12-2004

Volume One: National Standards Highway Design Guide, 2004

Maine Department of Transportation

Volume One

National Standards Highway Design Guide

NHS Highways

MaineDOT

REGISTRATION FORM
FOR
FUTURE GUIDE UPDATES

You now have the 2004 edition of the State of Maine Department of Transportation Highway Design Guide, Volumes I and II. The Department will be sending out periodic updates as they are approved. You are responsible to update this manual. If you pass it on to someone else, they are responsible to contact the Department with their name and address and to have your name removed from the Department's list. In order for you to get these updates, fill out the form below and send it back to the Department.

NAME : ____

COMPANY : ____

STREET : ____

TOWN : ________________________ STATE : ______________

ZIP : ______________

PHONE : ________________________

E-MAIL : ____

I received this manual from ________________________________
(Please remove their name from your list to receive updates)

Send this form to:

Highway Design Guide
c/o Office Manager
Highway Program
Maine Department of Transportation
16 State House Station
Augusta, Maine 04333

REGISTRATION FORM

FOR

FUTURE GUIDE UPDATES

You now have the 2004 edition of the State of Maine Department of Transportation Highway Design Guide, Volumes I and II. The Department will be sending out periodic updates as they are approved. You are responsible to update this manual. If you pass it on to someone else, they are responsible to contact the Department with their name and address and to have your name removed from the Department's list. In order for you to get these updates, fill out the form below and send it back to the Department.

NAME : ____

COMPANY : ____

STREET : ____

TOWN : __________________________ STATE : ________________

ZIP : ________________

PHONE : __________________________

E-MAIL : ____

I received this manual from ___________________________________

(Please remove their name from your list to receive updates)

Send this form to:

Highway Design Guide
c/o Office Manager
Highway Program
Maine Department of Transportation
16 State House Station
Augusta, Maine 04333

REGISTRATION FORM

FOR

FUTURE GUIDE UPDATES

You now have the 2004 edition of the State of Maine Department of Transportation Highway Design Guide, Volumes I and II. The Department will be sending out periodic updates as they are approved. You are responsible to update this manual. If you pass it on to someone else, they are responsible to contact the Department with their name and address and to have your name removed from the Department's list. In order for you to get these updates, fill out the form below and send it back to the Department.

NAME : ____

COMPANY : ____

STREET : ____

TOWN : ___________________________ STATE : _________________

ZIP : _________________

PHONE : ___________________________

E-MAIL : ____

I received this manual from ____________________________________

(Please remove their name from your list to receive updates)

Send this form to:

Highway Design Guide
c/o Office Manager
Highway Program
Maine Department of Transportation
16 State House Station
Augusta, Maine 04333

January 2008

How to Use this Guide

The *MaineDOT Highway Design Guide* has been developed to provide uniform design practices for Department and consultant personnel preparing contract plans for Department projects. The highway designer should attempt to meet all criteria presented in the guide. Where both desirable and minimum criteria are available, the designer should meet the desirable criteria if practical. However, this guide should not be considered a standard which must be met regardless of impacts.

The guide presents most of the information normally required in the design of a highway project; however it is impossible to address every situation which the designer will encounter. Therefore designers must exercise good judgment on individual projects and frequently be innovative in their approach to highway design. This may require additional research into highway literature.

Each page contains the page issue date in the upper left hand corner. The page number is located on the top in the middle with the section name underneath it. Pages, figures and tables are numbered consecutively throughout each chapter. The Department will provide revisions of the *Highway Design Guide* as they are made in the future if the holder has returned the "Registration Form for Future Guide Updates" that is included with the guide.

The *MaineDOT Highway Design Guide* is divided into two volumes:

- Volume I is based on the National Standards as set forth by the American Association of State Highway and Transportation Officials (AASHTO) in *A Policy of Geometric Design of Highways and Streets*. This volume of the Guide may be utilized for all State roadway projects but <u>must</u> be utilized for all projects on the National Highway System (NHS).

- Volume II is based on standards developed for the State of Maine and may be utilized for all non-NHS roadway projects.

If there are errors discovered in the *Highway Design Guide* or you have questions regarding any part please contact the following:

Robert Carrell
Highway Program
(207) 624-3370

Jonathan French
Highway Program
(207) 624-3372

Maine Department of Transportation
16 State House Station
Augusta, ME 04333-0016

Table of Contents

MaineDOT HIGHWAY DESIGN GUIDE

Table of Contents
(Continued)

Table of Contents
(Continued)

CHAPTER ONE

PROJECT DEVELOPMENT PROCESS

Volume I

- Highway Design Guide - National Standards

December 2004

Chapter One

TABLE OF CONTENTS

Page

Chapter One
PROJECT DEVELOPMENT TEAM PROCESS

1-1 INTRODUCTION

This chapter outlines the typical steps involved in the development of a project for the Urban & Arterial Highway Program. This chapter provides a reference for those involved in the delivery of projects, and provides for some consistency in the way we do things. The process is expected to evolve as we discover better ways to do things, and it will be important for team members to stay current.
The process is laid out in the order that a project will flow through the process. It explains all Milestones and Activities that are encountered. The Activities' numbers, when listed, correspond to the activity numbers used on Pay and Expense Vouchers.

Glossary of terms used in this chapter.

Regional Team – For the U&AH Program, this team consists of individuals with varied functional backgrounds. Typically; Design, Construction, Right of Way, Utilities, Geotechnical are represented. Each team has clerical support and is led by a Project Manager. ENV provides a dedicated liaison to their Bureau that interacts with the U&AHP teams.
Project Team – A group of individuals responsible for delivery and construction of a particular project. This team can be supplemented by outside consultants for various functions when needs arise.
Core Group – This group is led by the Project Manager and consists of the Project Manager, Assistant Project Manager, and the Appraiser III. This group is responsible for schedule, budget and scope decisions for all projects assigned to each Regional Team.
Project Team Meeting – This meeting is project specific and involves appropriate team and resource members.
Management Team – The Management Team consists of the Program Manager, Assistant Program Manager, Function Managers and Project Managers. The Core Management Team consists of the Program Manager, Assistant Program Manager, Construction and Design Support Managers.

1-2 NON-ACTIVITY MEETINGS

Several meetings are specifically scheduled to happen at a particular phase in the process and are detailed later on in the chapter when they occur. However, there are several types of meetings that may take place at any time throughout the process.

Coach Point Meeting – If, at any point in the process, the Team needs a decision beyond the scope of its authority (typically scope, budget, schedule, project viability), any member may request a Coach Point Meeting. Program Managers and other experts from the appropriate functions and levels of authority will be invited to attend, and they will work with the Team to identify the appropriate course of action.

Team Meeting – These meetings should be set at a regular interval such as every week, every other week or the first and third Tuesdays of every month. These meetings can be a good forum for specific project meetings such as the Initial Team Meeting, the Midway Team Meeting and the Final Team Meeting. Team Meetings can be held in the building, on site or at any other suitable location. The following ground rules, or a similar set agreed upon by the team, should be followed.

Team ground rules:

- All Members are invited and are expected to attend.
- An agenda and backup information is provided.
- Consensus is used for decision making.
- Minutes are taken and distributed.
- Other ground rules may be utilized as agreed upon by the Team.

Program Project Progress Meeting – The Program Management Team and each Core Team will attend a monthly meeting. The purpose of the meeting is to update Program Management on the progress of the projects due to be advertised in the next 12 month period.

Public Informational Meeting - If the project had been identified as having a "substantial public interest" an informational meeting or hearing may be necessary to update the public on the project's progress.

1-3 TEAM MEMBER EXPECTATIONS

Throughout the project development process there are certain responsibilities that are incumbent on each member of the Team.

- The Project Manager is responsible for keeping the schedule and budget up to date.
- The Project Manager notifies Program Management about any schedule and budget changes that affect the project, so that reporting systems can be updated.
- The Team Members will provide guidance to the Project Manager and Team as to their progress and when they need assistance to continue with the project. This should be done well in advance of the point of need.
- The Team is responsible for managing the project within budget and finding ways to further reduce costs even below original budget. If the Team reaches a point where the project budget

will not balance through reallocation of funds among the team's assigned projects, then the Project Manager should seek assistance from the Assistant Program Manager. For further guidance, see Administrative Policy Memorandum 161 (APM 161, dated 6/18/97). Throughout the budget management process, there should be consultation with members affected by proposed changes in the budget line items. Communication with all team members is crucial in developing realistic cost estimates.

When I serve on a team, I accept my responsibility to:

- ✓ participate and communicate;
- ✓ be a proactive problem-solver;
- ✓ be prepared and be ready to make decisions;
- ✓ think beyond my discipline;
- ✓ trust and respect; and be accountable for Team performance.

1-4 PROJECT DEVELOPMENT PROCESS

A Scoping Report is provided to the Urban & Arterial Highway Program by Planning prior to kickoff. A meeting with Planning at this time is discretionary.

Urban & Arterial Highway Program reviews the Sensible Transportation Policy Act level, the expected NEPA level (with input and advice from ENV), and the previously established kickoff date to determine if any adjustments are required, and identifies the public participation process to be used based upon established criteria.

Activities;
ACTIVATE PCE FUNDS
The Project Manager ensures that the Kick-off date is valid. At this point funds need to be activated through the Capital Resources Group within the Bureau.

1-4.1 Milestone PROJECT KICKOFF

The project has officially begun. (This should not be confused with the Initial Team Meeting, which comes later.) The project is assigned to the respective Arterial Team Region. The Project Manager reviews all information received from Planning, and may meet with a planning representative or with Regional Planners. This meeting can provide the Project Manager with

additional information pertaining to the project scope, funding, commitments, or any other background information that may not be clear.

The Project Manager and the Team Members begin collecting preliminary data. As much preliminary information as possible is gathered in preparation for the Initial Team Meeting.

Activities;

R 35 EXISTING R/W OWNERSHIP

Valuation and Zoning data are compiled from Maine DOT, Town and MARETA files. The research section compiles tax maps and assessments, Property Owner mailing list and other Right of Way information. The Right of Way scoping report is put together.

R 38 INITIAL UTILITY CONTACTS

The first letter to Utilities and Railroads is sent out. A list of Railroads and Utilities is sent to the Project Manager, Designer and Survey Coordinator. The Survey Section confirms locations of the Utilities in the field. Traffic and Multi-modal facilities within the Project Limits are identified and Utility related accidents are compliled.

INITIAL CONTACTS TOWN, FEDS, MPOs

The Project Manager contacts the municipality and other Local and Regional Planning Organizations.

S 45 PRELIMINARY SURVEY

The scope of the project is verified by the Survey Section. The GPS control is set and existing Right of Way and Survey plans gathered. The Survey Section obtains the Utility Contacts and Property Owner Lists. The Utility companies are notified through Digsafe or other means to mark their underground facilities. MX and MicroStation models are then created, edited and transmitted to the Team

D 20 PRELIMINARY DATA GATHERING (DESIGNERS)

Any existing plans from the vault are acquired. Discussions with Maintenance and Operations and Municipal Officials should begin in order to better understand Project parameters.

G 25 PRELIMINARY GEOTECH INFORMATION PHASE I

The Geotech Team Member reviews the geology maps and requests existing Utility information from the Utility Team Member. The existing soil reports are reviewed for relevant information such as plans and borings.

E 40 PHASE I ENVIRONMENTAL EVALUATION

At this stage the Preliminary Wetland Delineation, Preliminary Surface Water Evaluation, Preliminary Hazardous Waste Assessment, Preliminary Landscape Scoping, Preliminary

Mitigation Planning, 106 Identification and 4F Preliminary Identification are set. Initial Fisheries comments are sought.

PRELIMINARY DATA GATHERING (GENERAL)

The Team Members also begin to prepare their budget for the project. An initial field inspection or Coachpoint meeting may also take place at this time in order to confirm the scope.

Ongoing contact with the municipality is necessary to keep them informed of progress.

Maintenance representatives from the Division Office (usually the Division Traffic Engineer and the project area Maintenance Foreman or Bridge Manager) are contacted for their initial comments and concerns.

On projects with federal oversight, either the FHWA Design & Pavement Management Engineer or the FHWA Bridge Engineer must be contacted for their comments or concerns.

Many of these initial contacts may be addressed through an initial field inspection.

1-4.2 Milestone INITIAL TEAM MEETING

This Point of Communication is done as a meeting with all Team Members, and should occur for all projects. The meeting should be arranged to allow all Team Members to be present. At this meeting, all information gathered by the Team is shared and discussed to help identify constraints. The feasibility of the Master Schedule is reviewed along with the setting of the Milestone Dates and the Project Budget.

Activities;

R 35 BASE R/W MAPPING

Property Owner Reports, Survey, Titles and Tax Maps are gathered. Existing Property Lines and Right of Way is plotted on the survey.

D 25 PRELIMINARY DRAINAGE DESIGN

Regional Hydrology is requested from ENV. Rough flows are calculated and initial pipe sizes and locations are determined. The Designer and Geotech often take a field trip to see how the existing drainage functions. Preliminary recommendations are given to the team.

R38 PRELIMINARY UTILITY COORDINATION

A field inspection to look at existing Utilities is conducted. Comments received from the Utility companies are reviewed and it is determined if more survey is required for utility concerns.

T 20 PRELIMINARY TRAFFIC DESIGN

The Traffic Section supplies design considerations to the Designer who incorporates them into the design.

G 45 PRELIMINARY GEOTECH INFORMATION PHASE II

The Geotechnical Team Member requests borings. The boring logs are evaluated and preliminary recommendations are developed.

E 40 PHASE II ENVIRONMENTAL EVALUATION

Initial project information is delivered to the environmental specialty groups for comments. These comments are reviewed and delivered to the Team. At this time, an Interagency Meeting may be required between the DOT, state and Federal Environmental Agencies such as the Department of Environmental Protection, Department of Inland Fisheries, Wildlife and the Department of Marine Resources, Army Corps of Engineers and Environmental Protection Agency.

D 20 PRELIMINARY ALIGNMENT DESIGN

Based on the input from the Team, the designer develops the initial horizontal and vertical alignment. This alignment is shared with the Team and others as listed below for comments. There is a ten day comment period and everyone is expected to respond. By providing the alignment proposal at this stage, Team members will have advanced opportunity to review the proposal and consider any potential impacts from their perspective. Adjustments are made as warranted.

The alignment is distributed to the following:

- Project Team
- Program Management
- Bureau of Maintenance of Operations:
  - Regional Office
  - Highway/Bridge Maintenance Divisions (as appropriate)
  - Traffic Engineering Division
- Bureau of Project Development:
  - Assistant Director
  - Program services
- FHWA (on projects w/federal oversight)

A Team Meeting may be conducted as a follow-up to the distribution process. When it is expected that there will be substantial comments, a Team Meeting may take the place of the distribution process.

PRELIMINARY PUBLIC MEETING

The Project Manager schedules the meeting and notifies the Public Hearing Section or has the Team produce the Public Hearing Plan. Public Notice will be given in accordance with the National Environmental Policy Act (NEPA) and the Sensible Transportation Policy Act (STPA), if applicable. At this meeting, information already made known to the Project Manager is shared, along with the gathering of information from the Public. The Project Manager acts as the moderator and other Team Members may attend if appropriate. In some cases, this meeting may determine that a later full Public Meeting will not be necessary. After the meeting, the Project Manager communicates to the Team a summary of the input received. The Project Manager and Team members should review the transcript and follow-up with the public and municipality if necessary.

Then, the Project Manager and Team can begin utilizing all the information obtained to continue developing the project. Data and Public input are considered as all reasonable alternatives are investigated. The amount of preliminary engineering may vary between alternatives depending upon the continued viability of an alternative.

1-4.3 Milestone PRELIMINARY ALIGNMENT COMPLETE

It is expected that the Team has addressed all comments and concerns with regards to alignment. The alignment will remain unchanged through the remainder of the project development process. Any change to the alignment from beyond this step would essentially bring the project back to this point.

The Team will select the recommended alternative and the Preliminary Plan will be developed. The reasons for dismissal of other alternatives are discussed in the Preliminary Design Report's Summary of Engineering. This Preliminary Plan is a working document that should de reflective as to the context in which the Project is scoped and developed. The Preliminary Design Report development begins with the most general project information and continues to be developed throughout the process, with input from all Team Members.

Activities;

R 47 RELOCATION PLANNING

Preliminary Design and Proposed Right of Way cost data are compiled. It is determined if there will be any relocations due to the Project. If there are, a Preliminary Relocation Report and cost estimate are compiled. ENV is informed and the Property Owners are initially contacted.

R 53 PRELIMINARY R/W MAPPING

Data from the Preliminary Plan and Utility Coordinator are compiled to develop the proposed Right of Way.

R 38 ASSESS UTILITY R/W NEEDS
The Utilities are met with to discuss their Right of Way needs and these are communicated to the Mapper.

D 35 PRELIMINARY PLAN DEVELOPMENT
The Designer develops the 'gross' impacts for the approved alignment based on public input and Team comments. These are defined as impacts that do not take into effect constrictions due to Right of Way, Environment and other areas. The intent is to develop a baseline for use in defining minimization.

E 40 PHASE III ENVIRONMENTAL EVALUATION
The Hazardous Waste Plan, Long-term BMPs, Stormwater Analysis, Landscape Plan, Wetland Mitigation Plan, Property Assessment and Work Windows are developed. The level of Permit is determined and the draft permit written. Information is passed on to outside agencies.

Activities;
PRELIMINARY PLAN COMPLETE

R 47 R/W COST ESTIMATES
Right of Way Impacts and Valuation Data are gathered and the Right of Way cost estimate is compiled.

R 38 IDENTIFY UTILITY CONFLICTS
Aerial and underground Utility conflicts with the preliminary plan are identified.

MUNICIPAL FUNDING COORDINATION
The Municipalities are contacted and a draft Municipal Agreement written if necessary.

R 47 MAJOR IMPACTS CONTACT
Preliminary Design and Proposed Right of Way information are reviewed. If there are major impacts to properties, the affected Property Owners are contacted.

D40 PRELIMINARY CONSTRUCTION ESTIMATE
The Designer and Detailer develop rough quantities and costs and provide them to the Project Manager. The Estimate is incorporated into the Preliminary Design Report.

DRAFT PDR DISTRIBUTION
The PDR is distributed for comments within a 10 working day period. The PDR components distributed are a 2 page recommendation form, summary of preliminary engineering including

any design exceptions anticipated, and summary of avoidance and minimization measures included. The Preliminary Plan is also included in this distribution.

These will be distributed to the following:

- Project Team
- Program Management
- Bureau of Planning, Research and Community Services
- Bureau of Maintenance of Operations:
  - Regional Office
  - Highway/Bridge Maintenance Divisions (as appropriate)
  - Traffic Engineering Division
- Bureau of Project Development:
  - Assistant Director
  - Programming/Financing
  - Program services
- FHWA (on projects w/federal oversight)

The Project Manager collects and analyzes comments received on the PDR proposal. If no comments or only minor comments are received, the necessary adjustments are made to the PDR and Preliminary Plan. If significant comments are received, the Team will meet to review and address these comments. Final comments will be incorporated into the PDR and Preliminary Plan. If the Team has determined that the comments from the PDR lead to decisions outside the Team's discretion, a Coach Point Meeting may be held. Schedule and budget adjustments are requested from Program Management as necessary to accurately reflect the approved project scope.

Activities;

FORMAL PUBLIC MEETING

The project details are presented to the public by the Project Manager and other Team Members as appropriate. This could be a Public Meeting and/or a letter to the municipalities. The Public's comments and concerns are received. If a Public Meeting is held, the Project Manager communicates a brief summary of the Public Meeting to the Team.

Depending upon the comments received at the Public Meeting, a Coachpoint Meeting may be required. The Public concerns are reviewed and the project takes the appropriate course.

This is the last time that input into the scope of the project, alternative chosen and major design features such as roadway width, type of foundation, gravel or paved shoulders, alignment or type of structure will be considered. Once the Team is satisfied with the PDR and Preliminary Plan, only final design details normally will remain at issue.

MUNICIPAL AGREEMENTS

The Municipal Agreement is updated to reflect the current estimate and any commitments that should be recorded, then distributed to the municipality for approval.

NEPA COMPLETE

Environmental Process: A reference for team members outlining the ENV process is the "Project/Activity Clearance Status and Environmental Summary Sheet." Historical/archeological sign off must be complete prior to NEPA documentation. Documentation consists of completion of either a Categorical Exclusion, Environmental Assessment, or Environmental Impact Statement. Documentation must be complete before Negotiation and Acquisition activities can occur.

PDR COMPLETE READY FOR FINAL DESIGN

The PDR is signed by the Program Manager, as ready for Final Design. Any Design Exceptions have been documented in the PDR and, when the Project has federal oversight, needs to be signed off by an FHWA representative.

1-4.4 Milestone MIDWAY TEAM MEETING

Once input from the Public Meeting is obtained, and before final design begins, another project status update takes place to keep the Project Team informed of the project's progress. This meeting is highly recommended for most projects. If additional survey is needed, the Project Manager submits an additional survey request to the Survey Coordinator.

Final Design Begins: Once a decision is made to proceed with final development of the project after public participation, final design begins. At this time, the scope and applicable standards have been determined, and the PDR has been approved. It is expected that the Team has addressed all comments and concerns and that the scope and standards will remain unchanged through the remainder of the project development process.

Activities;

R65 VALUATION

It is determined if the waver process will be used as the Damage Estimate is compiled. The Appraisal report is put together.

R68 NEGOTIATION

Negotiation with the Property Owners takes place.

D 45 FINAL HIGHWAY DESIGN
The design is refined based on comments from the Public and the Team. The Geometrics, Details and Drainage are refined. Special details and special provisions are written as the plans are created.

T25 FINAL TRAFFIC DESIGN
Final recommendations from Traffic are incorporated into the plans by the Designer.

G50 FINAL GEOTECH DESIGN/REPORT
Recommendations on settlement and wall details are developed. (If additional borings are needed to supplement previous findings, they are requested at this stage.) The Final Soils Report is written.

E50 PHASE I ENVIRONMENTAL COORDINATION
The BMP locations, Impacts and Mitigation Plan are finalized. The final Permit Application is submitted. Special Provisions 105, 656 and Hazardous Waste are finalized. Erosion and Sedimentation Control quantities, Hazardous Waste quantities and Landscape Items are estimated. Well sampling is started.

1-4.5 Milestone PLAN IMPACTS COMPLETE

Upon completion of the design, but prior to the completion of the plan details (detail sheets, final estimate, etc.), the 75 - 80 % plans are distributed. This distribution includes the following:

(There is a 10 working day period for detailed comments.)

- Project Team
- Program Management
- Bureau of Maintenance & Operations Augusta Office
- Bureau of Maintenance & Operations Regional Office
- FHWA (on project w/federal oversight)

As a result of comments received from the 75 - 80 % plan distribution, minor adjustment may be necessary in the design details. The project Team needs to address any adjustments that may need to be incorporated in the project plans. Team Members will be advised how their comments were addressed. It is also important to ensure that the project is still on track and will be advertised on time.

The project Team works to finalize the plan details. A check to see if the project remains within budget limitations is necessary at this time.

If cost is beyond decision authority of the Team, a Coach Point Meeting will be held to determine how to proceed with the project. A decision is made to advertise as is or to rework and reduce cost. The Team has decision authority if the project remains within the limits shown previously. Again, *it is expected and encouraged that savings will be gained to offset overruns.*

R74 RELOCATION IMPLEMENTATION

This activity can start after the Formal Public Hearing. The Relocation Report is reviewed. It is determined if there are any Business or Residential relocations. It is also determined if there are any signs or Personal Property takes. Owners are contacted.

R53 FINAL R/W MAPPING

This activity can start after the Formal Public Hearing. The Easements and Rights are added to the plan. Parcel set-ups and distances are added to the plan. The plan is reviewed for Negotiation and Final Design changes. The Final Right of Way Map is developed.

R74 R/W CONDEMNATION & ACQUISITION

The Titles are updated by the Legal Division. Final Offer Letters and Condemnation Package sent out.

R50 UTILITIES FINAL COORDINATION

A letter and plans are sent to the Utilities with particular issues marked. The pole list and other final relocations are received from the utilities involved. A Pre-Coordination meeting may be held at this time. The Clearing Contract, Utility Certificate and Specifications are prepared.

D65 FINAL ESTIMATE REVIEW

The Final Construction Estimate is developed and reviewed by the Team. This is incorporated into the PS&E package.

E50 PHASE II ENVIRONMENTAL COORDINATION

The Permit is received as well as approval for the Final Mitigation Plan. Quantities and Special Provisions are finalized.

S55 CONSTRUCTION SURVEY

The layout of the construction centerline can be done at this point.

R/W CERTIFIED

The Right of Way Certificate is completed and added to the PS&E Package.

UTILITIES CERTIFIED

The Utility Certificate is completed and added to the PS&E Package.

PS&E COMPLETE

The Plans, Specifications and Estimates for the Project are assembled into one package and reviewed by the Contract Coordinator.

ENVIRONMENTAL APPROVALS COMPLETE

The Environmental Documentation is packaged and added to the Contract Package.

1-4.6 Milestone CONTRACTS PACKAGE COMPLETE

The Project Manager finalizes and submits a PS&E package to the Contracts section. It includes final Plans, Specifications, and an Engineer's Estimate. This package will be reviewed to make sure all commitments are clearly understood, and responsibilities for meeting the commitments are assigned and communicated. Respective Team Members will be responsible for delivery of those products to the Project Manager. New Pay Items are put in to TRANSPORT and Special Provisions are sent to the Specification Engineer.

Activities;

PROJECT ADVERTISED

R/W and Utility Certification must be complete before advertise. The project is advertised and awarded. If the Contract Award Committee has concerns about the bid, it may meet with the Project Manager to discuss the situation.

Activities;

CONTRACT DATE

The Award Recommendation Form is completed and the Municipality is notified. The Construction Resident assigned to the project coordinates the Pre-Construction meeting.

E50 PHASE III ENVIRONMENTAL COORDINATION

Erosion and Sedimentation Plan and Hazardous Waste Plan are received from the Contractor and reviewed by ENV. Recommendations are given to the Construction Resident.

PRE-CONSTRUCTION APPROVALS

The Contractor delivers the Worker Safety Plan, Insurance Certificate, Soil Erosion Control Plan, Hazardous Waste Exposure Plan, Hazardous Spill Prevention Plan and Traffic Control Plan.

C30 CONSTRUCTION ADMINISTRATION

PRE-CONSTRUCTION MEETING

A Pre-Construction Meeting is held with the Team and the Contractor to discuss Plans, Specifications and Procedures for the Project. Usually a meeting with the Utilities is held jointly with this meeting.

CONSTRUCTION BEGINS

Construction of the project takes place. Proposed changes during construction that may affect project impacts, property owner compensation, or commitments to others, should be coordinated with Team Members whose interest may be affected. Should Change Orders or Extra Work Orders be required, appropriate Team Members are consulted for input.

Activities;

FINAL TEAM MEETING/INSPECTION

When construction is complete, the Project Manager and the Construction Resident arrange for an on site Final Inspection Team Meeting to review the project. The purpose of this communication is to provide another channel of direct feedback that will continue to improve our process. This Team meeting is recommended for most projects to discuss how the process worked during the development of the project. At the meeting, Team Members will discuss what went right, what went wrong, and how the project development process could be improved. At this same time, or at least prior to demobilization, the Project Manager should also arrange to review the project with a Maintenance representative.

Activities;

CONSTRUCTION COMPLETE

C50 FINAL CONSTRUCTION DOCUMENTATION

R 50 UTILITY/RAILROAD AGREEMENT RESOLUTIONS

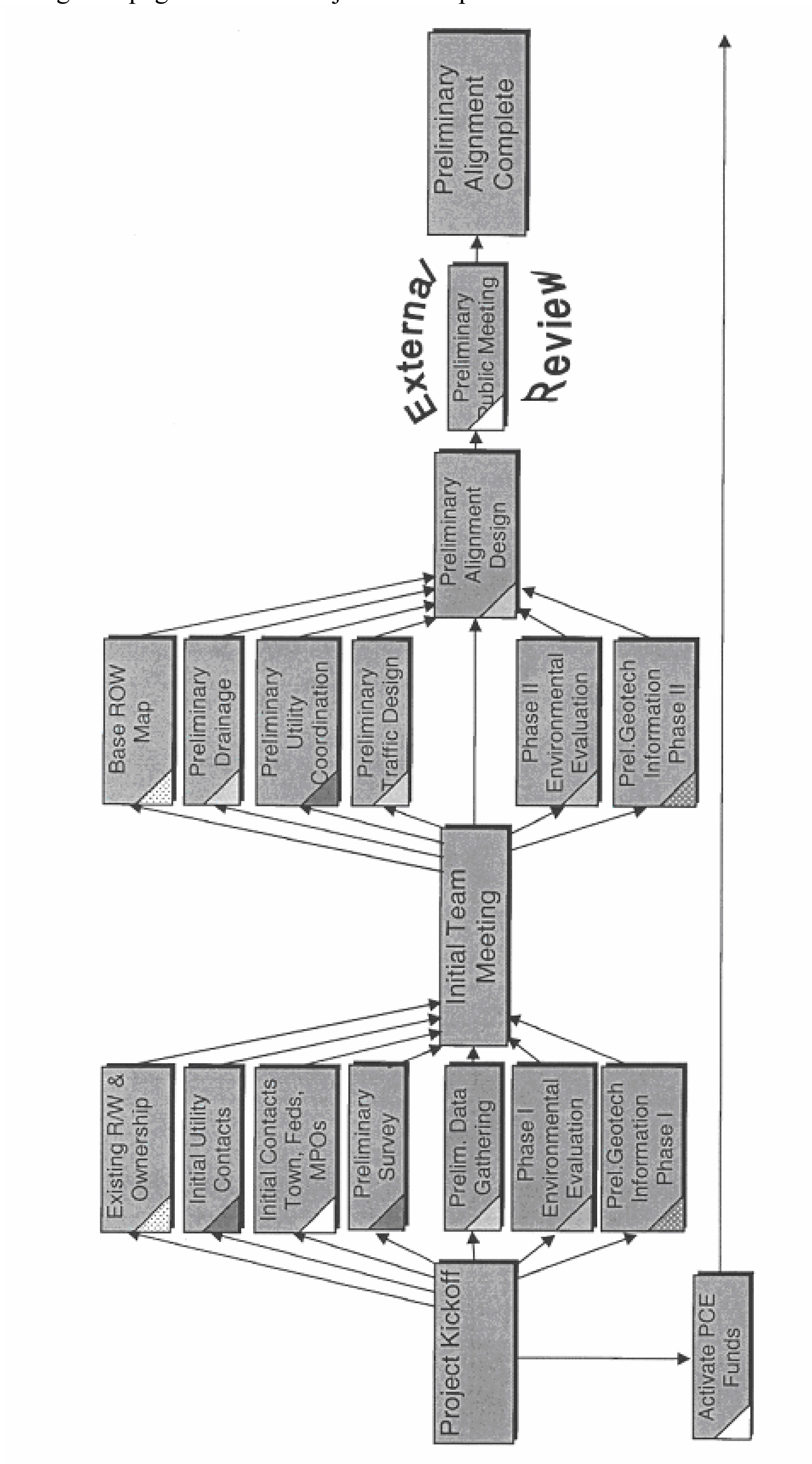
Utilities are notified of any field changes and given progress reports on the work. Final payments are made in accordance with the agreements.

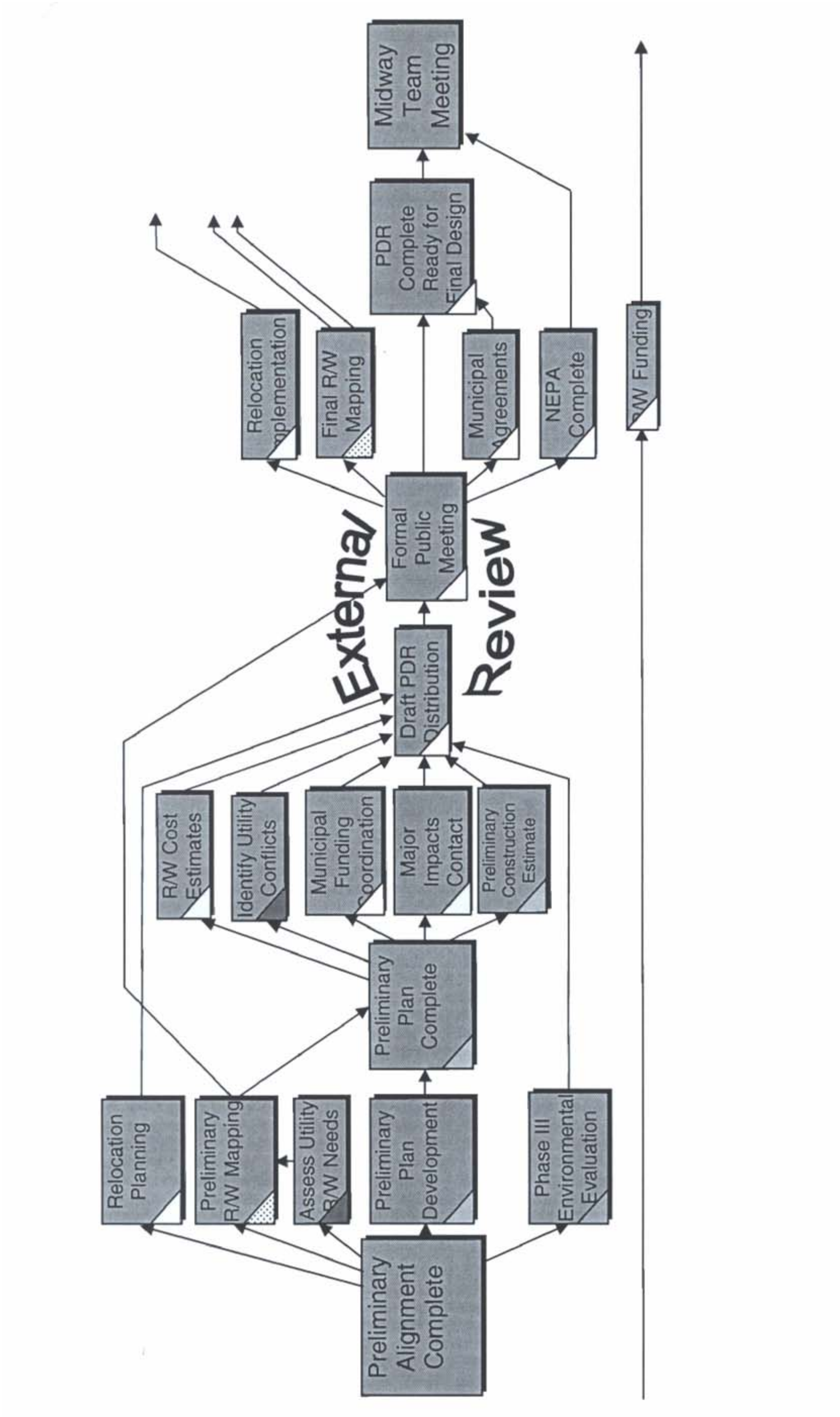
R/W DISPUTE RESOLUTION

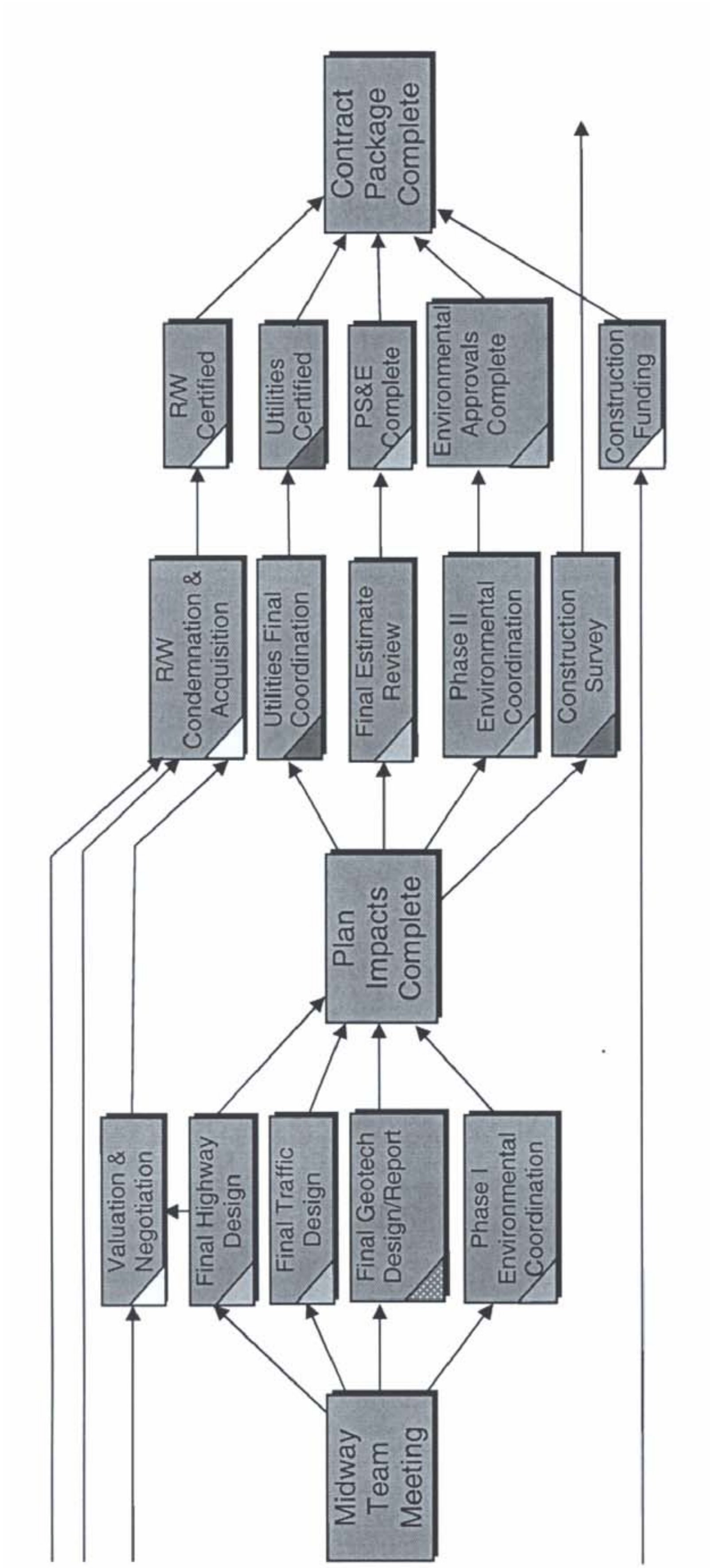
1-4.7 Milestone PROJECT COMPLETE

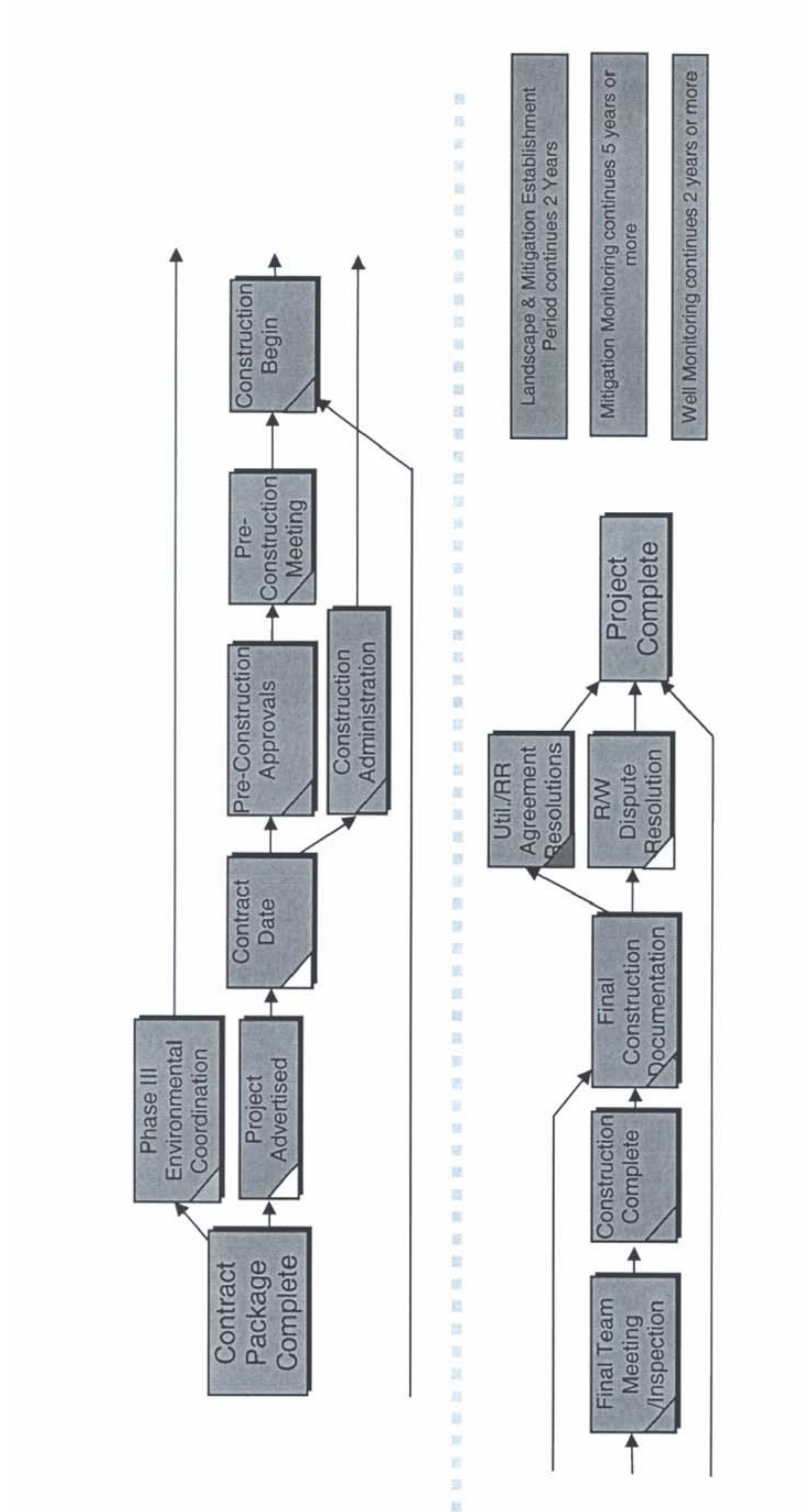
The Project is complete when: The Construction is complete; Team has reviewed and had a Final Team Meeting/Inspection; Utilities and Railroad agreements are closed out; As-Builts are complete; Right of Way disputes are settled; FHWA close-out and Finance and Administration is closed out.

The following four pages have the Project Development Process Chart.




Preliminary Alignment Complete
Relocation Planning
Preliminary R/W Mapping
Assess Utility R/W Needs
Preliminary Plan Development
Phase III Environmental Evaluation
Preliminary Plan Complete
R/W Cost Estimates
Identify Utility Conflicts
Municipal Funding oordination
Major Impacts Contact
Preliminary Construction Estimate
Draft PDR Distribution
External Review
Formal Public Meeting
Relocation mplementation
Final R/W Mapping
Municipal Agreements
NEPA Complete
PDR Complete Ready for Final Design
Midway Team Meeting
W Funding


Midway Team Meeting
Valuation & Negotiation
Final Highway Design
Final Traffic Design
Final Geotech Design/Report
Phase I Environmental Coordination
Plan Impacts Complete
R/W Condemnation & Acquisition
Utilities Final Coordination
Final Estimate Review
Phase II Environmental Coordination
Construction Survey
R/W Certified
Utilities Certified
PS&E Complete
Environmental Approvals Complete
Construction Funding
Contract Package Complete


Contract Package Complete
Phase III Environmental Coordination
Project Advertised
Contract Date
Pre-Construction Approvals
Construction Administration
Pre-Construction Meeting
Construction Begin
Final Team Meeting /Inspection
Construction Complete
Final Construction Documentation
Util./RR Agreement Resolutions
R/W Dispute Resolution
Project Complete
Landscape & Mitigation Establishment Period continues 2 Years
Mitigation Monitoring continues 5 years or more
Well Monitoring continues 2 years or more

CHAPTER TWO

PREPARATION OF PLANS

Volume I

- Highway Design Guide –

National Standards

Updated December 2013

Chapter Two

TABLE OF CONTENTS

Chapter Two

PREPARATION OF PLANS

The preparation of construction plans involves preparing a set of drawings with sufficient details on location, geometric configuration, quantities and specifications of work on a project. To ensure a consistent interpretation of the plans, each sheet should have a standard format and content, and the sheets should be assembled in the same sequence. This chapter presents guidelines for plan preparation to ensure that construction plans will be clearly and uniformly prepared by technicians, and will be correctly interpreted by contractors.

2-1 GENERAL

2-1.01 Record Plans

Record construction plans should be referenced for all projects on existing alignment. These plans may be retrieved from electronic storage media. The designer should retrieve prints of the record plans for the following project types:

1. Restoration/Resurfacing Projects. Record plans should be referenced for centerline information on all restoration/resurfacing and safety improvement projects on the existing alignment. Project numbers from the record plans should be referenced in the general notes of the proposed plans. Construction notes for these projects are typically placed on a separate sheet corresponding to stations on the record plans. Straight-line plans or additional field survey may be required where some new construction is involved or more detailed information is necessary. For example, additional cross sections may be included where guardrail elimination and/or slope flattening is warranted.

2. Rehabilitation and Reconstruction Projects. Record plans should be used as a reference only on rehabilitation and reconstruction projects. New field survey providing all existing details within the project limits should be obtained for design.

2-1.02 Plan Sheet Sizes and Layout

The standard full size sheet for all final construction plans should be plotted on 36 inch wide paper Cut plan sheets should have 100' overlaps for scales of 1" = 50' and 50' overlaps for scales of 1" = 25'

For Plan/Profile sheets, the corresponding profile is placed on the same sheet below the plan view. If there is too much detail or physical constraints such as steep hills or sharp curves, the profile could be placed on a separate sheet. Profile information is plotted from a combination of reports and graphical output from design software. When combining plan and profile sheets, the designer/detailer should align the centerline stations of the plan and the profile starting at the center of the sheet and proceeding toward the edges to account for curvilinear horizontal alignments.

2-1.03 Plan Sequence and Numbering

The number and type of sheets in the final construction plans are dependent on the project scope of work. Sheets in the plan set should be numbered in sequence. A restoration/resurfacing project will usually require fewer sheets than a new construction project. The typical assembled sequence for a complete set of construction plans will be (as required):

Title Sheet
Typical Sections
Estimated Quantities and Earthwork Summary
Drainage Sheet
General Notes
Construction Notes (if separate sheet used)
Special Details (e.g., slab walls, retaining walls, culvert connections, ledge undercuts)
Geotechnical Information Sheets (boring logs, existing pavement depths etc.)
Permanent Traffic Control
Bridge Plans
Bridge Details
Plan/Profile Sheets
Special Profiles – Drainage, Side Roads etc.(if used)
Geometrics and Curb Layout (if used)
Cross Sections
Special Cross Sections – Drainage, Side Roads etc (if used)
Stand-alone Plans (e.g., right-of-way plans, utility plans, landscaping plans)

Where the plan and profile are on separate sheets, plan sheets should be placed before the profile sheets in the assembled sequence.

2-1.04 Standard Abbreviations and Symbols

Standard abbreviations and symbols are presented in Appendices 2A and 2B at the end of the chapter. The designer should adhere to the established abbreviations and symbols in the preparation of plans to achieve uniformity from project to project.

2-1.05 Instructions for All Sheets

The following information will apply to all construction plan sheets:

1. Complete title bar information to the right of each page

2. Town and highway system number, program, project manager, designer, consultant (if applicable), and completion date also noted in right-hand title bar.

3. See the font table in Appendix 2G for the proper font type and size for each sheet in the plan package. Typically all proposed text shall be italicized uppercase with the exception of columnar data which should be mono-spaced uppercase format. However if text is in a table, italicized uppercase may be used.

2-2 TITLE SHEET

The title sheet is always Sheet No. 1, and it serves as the cover sheet for the remainder of the plans. See Figure 2-1 in Appendix 2H. It provides a considerable amount of information and serves as a general index and reference sheet for the project.

The following information should be included on all title sheets for construction plans:

1. Edit electronically (via MaineDOT customization) or manually the town(s) name, county name, route number and or street name, project number and project length to the nearest hundredth (0.00) mile in the center of the sheet.

2. Complete the lower right corner box with Project Location, Program Area, and Scope of Work.

   Project Location: Fill in with the location description from Projex. Verify the completeness and accuracy of the location description and adjust if necessary.

   Program Area: This would be either the Highway Program, the Bridge Program, or the Multi-Modal Program.

   Scope of Work: This consists of a brief description of the type of work as determined by the project's design and the project team.

3. Edit the Index of Sheets (indicate side road plans and cross sections, layout sheets, special details, grading plans, etc.) located in upper right portion of the sheet. Include all applicable sheet types and their corresponding sheet numbers ordered as indicated in Section 2-1.03

4. Any additional text that is added for notation purposes shall have an italicized upper case font. See the font table in Appendix 2G.

5. Edit Traffic Data: *(Enter multiple columns for projects with data for different segments)*
   a. Current AADT (indicate construction year).
   b. Future AADT (indicate design year).
   c. DHV - % of AADT
   d. DHV: Design Hour Volume
   e. % Heavy Trucks (AADT)
   f. % Heavy Trucks (DHV)

g. Directional Distribution (DHV): Percent of directional traffic volume during the DHV.
h. 18-kip Equivalent P 2.0 or P 2.5 (which ever applies): Equivalent number of 18-kip, single-axle loads (for pavement design).
i. Design Speed(mph): Design speed or, on overlays, "as posted."
j. Functional Class

6. Check the following signatures and dates in the title block:

   a. Commissioner and Chief Engineer
   b. Consultant Engineer (if applicable)

7. Check for seal of:

   a. Engineer of Record (engineer responsible for stamping plans)
   b. Consultant Engineer (if applicable)

8. Edit the text in the right-hand title bar with name of city/town and route number, project number and construction WIN. Edit the border information to show the sheet number. Edit the Project information section in title block with the pertinent information.

9. Check Layout Plan (not required on Federal-aid light resurfacing and railroad/highway grade crossing projects) to make sure it includes the following:

   a. Roadway blacked in for project length

   b. The beginning and ending stations of the project should be labeled along with the project number.

   c. Stations listed at increments of even multiples of 100’ along project, as determined by the length of the project and space constraints

   d. Show plan sheet boundaries along with sheet numbers that correspond to the same sheet numbering in the Index of Sheets.

   e. North arrow shown

f. Graphic scale should be in even stations.

g. Station equations shown (if applicable).

h. Prominent features such as side roads, waterways, railroads, etc., shown and labeled.

i. Side roads shown with leader line noting road name.

j. Direction to major towns or cities shown at each end of the project.

k. Town lines with towns labeled as well as the station where the town line crosses the design centerline

2-3 TYPICAL SECTION SHEET(S)

The typical section sheet(s) will follow the title sheet in a complete set of construction plans. Typical sections are prepared based on the cross section elements discussed in Chapter Six. Numerical criteria for the various cross section elements are provided in Chapters Seven and Eleven. Depending on the complexity of the project, one or more typical section sheets may be required. See Figure 2-2 in Appendix 2H.

The following information should be provided on all typical section sheets:

1. Edit text in right-hand title bar.

2. Standard proposed text shall be italicized upper case. See Appendix 2G for proper font types and sizes.

3. Typical sections checked for:

    a. Dimensions should be shown in decimal feet to the nearest hundredth of a foot and rounded to the nearest 0.05 feet horizontal and vertical. Layer thicknesses should be designated in decimal inches with the total section thickness rounded to the nearest half inch, except for overlays.

    c. Aggregate subbase volumes for travelway and shoulder areas should be recorded separately below each typical section. Subbase volumes should be calculated in cubic yards per 100 linear feet to the nearest hundredth (0.00) of a cubic yard.

    d. Types and depths of base and subbase courses noted. Total pavement depth should also be shown.

    e. Side slopes expressed as a ratio of horizontal distance to vertical distance.

    f. Cross slopes expressed in percent (%).

    g. On typical sections, subgrade cross slopes under the travel lanes should be parallel to travel lane cross slopes in both normal and superelevated conditions. The subgrade cross slope under the shoulder should be minus 2 percent in both normal and and superelevated conditions and labeled “-2%.”

4. Location of profile grade shown on each major typical section.

5. Superelevations and shoulder slopes should be shown to the nearest tenth of a percent in table form on the Typical Section sheet. If adequate room is not available on the Typical Section sheet, a separate Typical Section sheet may be used.

6. The following standard notes should be shown on Typical Section sheets:

   The pavement, base and subbase depths as shown on the plans are intended to be nominal.

   When superelevation exceeds the slope of the low side shoulder, the low side shoulders pavement shall have the same cross slope as the travel way.

   Crowns for both normal and superelevation sections for all courses of subbase and pavement shall be straight.

   The gravel quantity calculation is based on a 2” loam or dirty borrow depth. The actual depth may vary. See the General Notes.

   The algebraic difference between shoulder and travel lane cross slopes “rollover” shall not exceeed 8%.

   The stationing shown under each typical is approximate.

7. Ultimate design shown if project is to be staged.

8. Show limit of stage construction.

9. Show designated loam or dirty borrow areas and depths.

10. Station-to-station limits of each major typical pavement, aggregate, and shoulder section noted where feasible.

11. Curbs, sidewalks, guardrail, loam, etc., should be shown.

12. The following dimensions should be labeled on each typical as applicable:

a. Offset and vertical drop from centerline profile grade to the subgrade sideslope intercept in normal sections or from the edge of travelway in superelevated sections to the subgrade side slope intercept

b. Offset and vertical drop from centerline profile grade to the finished ditchline in normal sections or from the edge of travelway in superelevated sections to the finshed ditchline

c. Widths of travel lanes and shoulders

d. Width of subbase gravel extending beyond the edge of shoulder surface in box sections

13. Where slopes and dimensions are variable, label as such.

2-4 ESTIMATED QUANTITIES SHEET

All construction plans require an estimate of quantities summarized by pay item. The quantities should be recorded on a quantity sheet. See Figure 2-3 in Appendix 2H. The following information should be included on the quantity sheet:

1. Complete right-hand title box.

2. Estimated quantities listed in order by item number.

3. Asterisk before all items that are undetermined location and note at bottom.

4. Typically, the Earthwork Summary (see Standard Form in Appendix 2C) is here. Sometimes the sheet is too full and it needs to be put on a second quantity sheet or the construction notes.

5. When more than one project is included in a contract, the following items may be noted to be a percentage of the total contract cost:

    a. Field office
    b. Test facility items
    c. Mobilization, and all lump sum items that are included in more than one project

6. Follow rounding rules in Chapter Fourteen.

7. Use italicized uppercase font for the Estimated Quantity text and mono-spaced uppercase font for all Earthwork Summary text. See Appendix 2G for proper font types and sizes.

8. If a lump sump item is quantifiable, the quantity should be shown next to the lump sum item quantity on the Quantity Sheet.

2-5 DRAINAGE SUMMARY SHEET

All projects requiring drainage work should include a drainage summary sheet in the construction plans. See Figure 2-4. The location and quantity of each drainage item should be recorded on a drainage sheet. General notes are often included on the drainage summary sheet when space is available. The following information should be included on the drainage summary sheet:

1. Complete right-hand title box.

2. All drainage system components separated into major subdivisions (i.e., roadway drainage culverts, driveway culverts, catch basins, underdrains, etc.) and listed in station order.

3. Under culvert pipe Option III item and Type C underdrain items, all pipes shall be sized using smoothlined pipe. Comparable corrugated sizes shall be shown on the Drainage Summary Sheet unless smoothlined pipe is required.

4. Drainage summary text shall be italicized uppercase at all times. See Appendix 2G for proper font types and sizes.

2-6 GENERAL NOTES SHEET

The designer shall include a list of general notes in the construction plans providing overall information applicable to the project. The notes provided are not intended to be a complete set covering all problems that may arise on a project, but they do cover many recurring situations. General notes may vary from project to project and, if special conditions or requirements exist, notes should be modified or added accordingly. The following information should be included on the sheet:

1. Complete right-hand title box.

2. Text for general notes in this section shall be italicized uppercase font. See Appendix 2G for proper font types and sizes.

3. Geotechnical notes may be added if applicable. These notes are typically provided by the geotechnical team member.

See Figure 2-5 in Appendix 2H for a sample sheet.

A list of updated general notes can be found on the MaineDOT website at the following URL:

http://www.maine.gov/mdot/technicalpubs/documents/hwydg/vol1/generalnotes.doc

2-7 CONSTRUCTION NOTES SHEET

Construction notes are required to identify specific details of construction for a given project design. A minimum number of notes should be used, although a clear indication of the intent of the plans is necessary.

Generally, all construction notes (excluding drainage notes) are provided on the plan/profile sheet(s). See Figure 2-7 in Appendix 2H for example notes on the plan/profile sheets. Construction notes may be placed on a separate sheet for full construction urban projects and for overlay projects when referring to the record plans. See Figure 2-6 in Appendix 2H for a sample Construction Notes Sheet. On urban projects involving detailed designs, this will help alleviate congested plans that are difficult to read.

Construction notes should be identified by the item number and item description, if applicable, followed by the station locations. Ascertain that all work shown is covered by a direct payment item or that payment is included indirectly in another item. If work is not so covered, the supplemental specifications or general notes should be explicit on the compensation intended.

Construction notes should always be put in numerical order in case of computerized changes. Text for notes on this sheet shall be mono-spaced uppercase font. See Appendix 2G for proper font types and sizes.

See Appendix 2E for typical construction notes and where they should be shown on the plans.

2-8 SPECIAL DETAILS SHEET(S)

Some design details that are not covered in the Standard Details or Typical Sections may require a Special Detail Sheet as determined on a project specific basis.

Special Detail Sheets may be needed for design components such as:

- Retaining walls
- Non-standard culvert connections
- Box culvert extensions
- Special guardrail details not covered in the Standard Details
- Ledge undercut transitions (See Appendix 2F for sample sheet)

Each Special Detail sheet should be listed separately in the Index of Sheets on the Title Sheet. Example: *Special Detail – Ledge Undercut*

Sample Special Detail sheets may be found in Appendix 2F.

2-9 PLAN/PROFILE SHEET(S)

The plan/profile sheet(s) presents the vertical and horizontal alignments, topography, right-of-way and other details necessary for the construction of the project. Figure 2-6 illustrates a plan/profile sheet typically used by the Department. Complex projects involving interchange ramps and large urban intersections may require a separate plan sheet and profile sheet to clearly indicate construction details.

To ensure consistent preparation of the plan/profile sheets, the designer should follow these guidelines below. When the plan sheet and profile sheet are separate, use the applicable notes for each sheet.

PLAN

1. Minimum of 25 feet of existing center line shown on each end of project regardless of scale if possible.

2. Refer to the Standard Abbreviations (Appendix 2B) and the Standard Symbols (Appendix 2C) for proper labeling. Proper font styles and sizes can be found in Fonts (Appendix 2G).

3. Complete right-hand title bar.

4. Stationing of the highway mainline should be shown increasing from left to right on the plan.

5. North arrow.

6. Show the location of temporary and proposed utility structures (i.e. poles, manholes, mains etc.)

7. Station of town, county, compact, compact-urban or urban lines shown.

8. Information should be shown for the construction of approaches and tapers from the match point limit of work to the project beginning and ending points. Pavement taper widths and gravel transition taper widths shall be noted.

9. Radii, center of curve points and width of pavement should be shown on all approach roads and paved intersections. Curve radii at non-standard driveways should be indicated on the plans.

10. Locations of channel diversions, inlet and outlet ditches shown.

11. Show and label proposed drainage structures.

12. Locations of bridges shown and reference note made to bridge plans.

13. All construction slope lines shown.

13. Clearing limit lines shown for all clearing, selective clearing and thinning areas.

14. Proposed guardrail shown

15. Right-of-way easement lines, reserve areas noted if applicable, property owner's names, property lines, existing R/W lines, access control, and proposed R/W lines shown. Also show grading limit lines and construction limit lines

16. Equations and angles shown on all side road alignments on plans.

17. Construction notes outlining work and bid items to accomplish the work shall be shown on plans, construction notes sheet, or cross-sections. See Appendix 2E,

18. Show edge of travel way and edge of shoulder on plans

19. Show bridge and railroad clearance diagrams in the profiles.

20. Ditch drainage lines and arrows shown, indicating direction of flow.

21. Limit of work shown on all side roads and on mainline if different from beginning and end of project limits.

22. Standard text shall be italicized uppercase at all times except for text in columnar format, which shall be mono-spaced uppercase text. See Appendix 2G for proper font types and sizes.

23. Label project number; begin/end stations and limits of work.

24. Label all highways with applicable route numbers and roadway names.

25. Town and highway numbers noted on all sheets in the right-hand title bar

26. Note existing drainage structures to be removed.

27. All single trees and stumps, regardless of size outside clearing or selective clearing and thinning areas, should be noted to be removed. Do not note trees to be saved. Do not note removal of single trees within a clearing area.

28. Note existing buildings to be removed. See Chapter Fourteen for how to note.

29. Topsoil salvage areas noted as needed

30. Note the removal of existing pavement areas outside of construction limits. Pavement that is to be removed in areas outside of the construction limits shown on the plans should be cross-hatched and labeled "Excavate, loam and seed."

31. Plans and cross sections cross-checked to ensure correctness.

32. Roadway and shoulder widths should be indicated on the plans at the beginning and end of each plan sheet and at any change in the width.

33. Horizontal curve data should be recorded on the plan for the construction centerline. Horizontal curve data should always be recorded on the inside of the curve, if possible. When a curve runs on successive plan sheets, the curve data should appear on both sheets. The curve data and degree of accuracy required for each horizontal curve within the project limits is provided below:

    a. PI -- two decimals
    b. Δ -- nearest tenth second
    c. D -- nearest tenth second
    d. T -- two decimals
    e. L -- two decimals

f. R -- two decimals
g. E -- two decimals

Controlling stations (including the PC, PT, station equations and angle points) should be recorded on a line drawn perpendicular to the construction centerline toward the inside of the curve. Stations should be recorded to the nearest hundredths (0+00.00) station. A triangle should be provided on the plans to indicate angle points, and a circle should be provided to indicate all other controlling stations.

34. Alignment bearings on tangents should be noted to the nearest tenth of a second.

35. Center of curve points for radii and should be shown and the station/offsets and coordinates provided unless that point falls with a physically unattainable area such as a building.

36. On complex projects, separate layout sheets may be required in the construction plans to define special details not provided on the plan sheets. The need for special details will be determined on a project-by-project basis.

PROFILE

1. Limit of work shown on all side roads and on mainline if different from beginning and end of project limits.

2. High-water elevation and year of occurrence shown for projects near flood areas when relevant.

3. Dashed lines and symbols should be used to indicate existing profile elements, and solid lines and symbols shall be used to indicate proposed profile elements.

4. Complete right-hand title bar.

5. Label project number; begin/end stations and limits of work.

6. Refer to the Standard Abbreviations (Appendix 2B) and the Standard Symbols (Appendix 2C) for proper labeling.

7. Closed drainage systems may be plotted on the profile when necessary.

8. Plot ledge and ledge transitions if practical

9. Standard text shall be italicized uppercase at all times. Refer to Appendix 2G

10. Vertical curve data should be provided on the profile for each vertical curve on the construction centerline. Curve data should be recorded beneath crest vertical curves and above sag vertical curves on a horizontal line drawn from the PVC to the PVT. When a vertical curve runs on successive profile sheets, the curve data should appear on both sheets. The curve data and degree of accuracy required for each vertical curve within the project limits is provided below: PVI Station / elevation below a sag curve, above a crest curve.

L	--	no decimal
SSD/HLSD	--	no decimal
E	--	three decimals (.001)

11. Station and elevation at PVC, PVI and PVT location. All data shall be shown to the nearest hundredth decimal

12. High and low points in the proposed profile should be marked with a leader arrow, station and elevation.

13. Grade line checked for the following:

    - Percent grades recorded to the nearest hundredth (0.00) percent denoted with a plus or minus for direction of grade.
    - PI elevation recorded to the nearest hundredth (0.00) foot, denoted by a triangle pointing to the inside of the cuve.
    - Rural finish grades every 50’, recorded to the hundredth (0.00) of a foot.
    - Urban finish grades every 25’, recorded to the nearest hundredth (0.00) of a foot.

14. Additional profiles may be required for side roads, driveways and curb lines that are affected by the mainline construction. The additional profiles should be indicated off the mainline on the profile sheet or a separate profile sheet may be used if necessary.

2-10 GEOMETRIC LAYOUT SHEET(S)

Detail sheets may be necessary to define the geometric layout of an intersection, islands and/or curbing. The need for geometric layout sheets with be determined on a project by project basis and will depend on the amount of varying geometry and space needs to document it.

If only a few geometric point locations are necessary for layout, a separate geometric sheet may not be necessary. Instead the key geometric points could be labeled on the plan sheet keyed to a chart with stations and offsets to those points.

To ensure consistent preparation of the geometric layout sheets, the designer should show the following:

1. North arrow
2. Street name/route number
3. CB/MH symbols
4. Roadway centerlines and gutter line alignments should be labeled and referenced with station and offset listings to key geometric points
5. Center of curve points for radii and should be shown and the station/offsets and coordinates provided unless that point falls with a physically unattainable area such as a building.
6. Curb symbols
7. Key Geometric points labeled with tick mark and point number
    - Terminal curb points
    - Catch basin header points
    - Wheel chair ramp opening
    - Drive/Entrance openings
    - Curbed islands
    - Angle points in gutter line – if any
    - PC/PT points in gutter line

8. Geometric reports for gutter line alignments shown with coordinates (Roadway centerline geometric reports not necessary because they are already shown on plan sheets)

9. Station and offset reports with coordinates keyed to point numbers shown on gutter line/Geometric features

2-11 CROSS SECTION SHEETS

The cross section sheets represent the tranverse sections of the existing ground line and the proposed design at various points along the design centerline. Cross sections should be cut when possible for features such as entrances, culverts, catch basins and widenings for guardrail. Cross sections should be generally be drawn at 25' intervals for urban projects and at 50' intervals for rural projects and should be drawn on a sheet provided by the CADD package with a grid pattern at a scale of 1" = 5' horizontally and vertically. See Figures 2-8 and 2-9 in Appendix 2H.

Cross sections may be plotted in a landscape orientation in order to minimize "foldbacks" and provide a better fit. If it proves necessary to utilize a smaller scale to allow for a better fit of topography, care should be taken to ensure readability when plans are printed half size.

The designer/detailer should follow these guidelines in the preparation of cross section sheets:

1. Dashed lines and symbols shall be used to indicate existing cross section elements, and solid lines and symbols shall be used to indicate proposed cross section elements.

2. Individual cross sections are typically oriented from bottom to top of each cross section sheet in order of increasing station.

3. Edit text in the right hand title bar including the following: appropriate "record" boxes on left of sheet completed to denote who checked it and when, who revised it and when, the designer/detailer, and any field changes that were made. Town and highway system number noted in the lower right hand corner. Station range should also be noted for each sheet.

4. Label station and project number of beginning and ending of proposed project

5. Volumes for earthwork items such as earth excavation (cut), fill, rock excavation, muck excavation, waste storage, grubbing in fill, loam salvage and variable depth gravel should be calculated between individual cross sections and noted at even intervals on the sections. Volumes shown should be rounded to the nearest whole cubic yard.

6. Volumes calculated in cubic yards, totaled and tabulated on the Earthwork Summary Computation Worksheet in Appendix 2C and also should be noted in the Earthwork Summary on the Estimated Quantities Sheet.

7. Station-to-station depths of aggregate base and subbase courses noted if not constant throughout project.

8. Show design cross slopes on each cross section

9. On cross sections adjacent to side roads that have separate alignments and cross sections, a match line should be shown and the side road labeled.

10. Show intended driveway slopes and transitions including widths and slopes. See sample cross section sheet Figure 2-10 in Appendix 2H

11. When available the locations of rock and muck should be plotted

12. Elevations and offsets of all non-standard ditches shown.

13. Elevations of all underdrain shown.

14. Ditch elevations and gutter grades checked for proper slope through superelevation transitions and long vertical curves.

15. Grubbing in fill noted and shown in applicable areas.

16. All existing drainage information should be plotted.

17. Proposed drainage information should be plotted. The type of structure should be provided, and the length, size, direction of flow, inlet and outlet flowline elevations, type of material, thickness (if necessary), skew angle (if any) and end treatment should be indicated for all pipe culverts and underdrain.

18. Existing ground slopes steeper than 2:1 noted and plotted to be benched.

19. Existing and proposed utilities shown with proper symbols.

20. Plot trees on sections.

21. Ditch grades checked for required erosion protection.

22. Place ditch arrows showing direction of flow.

22. Pavement and subbase depths noted for side roads and approaches if typical sections not drawn.

23. Individual cross sections should provide the proposed profile grade elevation directly above the centerline. Elevations should be recorded to the nearest hundredth (0.00) of a foot. Offsets from the alternate centerline to the construction centerline should be provided if not coincident with the alternate centerline. Offsets should be recorded to the nearest hundredth (0.00) of a foot.

24. Station-to-station of box sections noted if not constant throughout project.

25. See Appendix 2H for examples of construction notes that would typically be placed on the cross sections

Appendix 2A

STANDARD ABBREVIATIONS

STANDARD ABBREVIATIONS

I. BASES

GRAV	Gravel
CR GRAV	Crushed Gravel
BIT MAC	Bituminous Macadam
BIT CONC	Bituminous Concrete
CRSE	Course

II. CEMENT and CONCRETE

CEM	Cement
CONC	Concrete
PORT	Portland
REINF	Reinforcing

III. CENTERLINE DATA

CL	Centerline
CONST	Construction
Δ	Delta or Central Angle of Curve
PI	Point of Intersection of two Tangents
R	Radius Curve
T	Tangent Distance
L	Length of Curve
E	External Distance
PC	Beginning of Curve (Point of Curvature)
PT	Point of Tangent
POC	Point on Curve
POST	Point of Subtangent
POT	Point on Tangent
PCC	Point of Compound Curvature
PRC	Point of Reverse Curvature
SB	Southbound
NB	Northbound
CE	Control Edge
EQ	Equation

IV. PROFILE DATA

PVI	Point of Vertical Intersection
PVC	Point of Vertical Curve
PVT	Point of Vertical Tangent
HLSD	Headlight Sight Distance
SSD	Stopping Sight Distance
PSD	Passing Sight Distance

V. EARTHWORK

EXC	Excavation
EA EXC	Earth Excavation
RK EXC	Rock Excavation
STR EXC	Structural Excavation

VI. FOR QUANTITIES ON CROSS SECTIONS

C	Cut or Earth Excavation
F	Fill
G	Grubbing in Fill
R	Rock or Ledge Excavation
M	Muck Excavation
GRAN B	Granular Borrow
GRAV B	Gravel Borrow
SAND B	Sand Borrow
VG	Variable Gravel

VII. GENERAL

ASPH	Asphalt
BLDG	Building
BM	Bench Mark
CLL	Construction Limit Line
DR	Drive
EP	Edge of Pavement
ENT	Entrance
FE	Field Entrance
FP	Flag Pole
GRAV DR	Gravel Drive
GAR	Garage
GR	Guardrail
HI	Height of Instrument
HORIZ	Horizontal
HO	House
LT	Left
PO	Porch
RD	Road
RDWY	Roadway
RT	Right
RET WALL	Retaining Wall
RR	Railroad
SHLD	Shoulder
ST	Street
STA	Station
SW	Sidewalk
SKWD AHD	Skewed Ahead
SKWD BK	Skewed Back
SURF	Surface

TP	Turning Point
TW	Edge Travel Way
VERT	Vertical
WL	Woods Line

VIII. PIPES and DRAINAGE

ACMP	Aluminum Corrugated Metal Pipe
ACCMP	Asphalt Coated Corrugated Metal Pipe
CB	Catch Basin
CCL	Culvert Ceiling Level
CIP	Cast Iron Pipe
CMP	Corrugated Metal Pipe
CULV	Culvert
CULV CONN	Culvert Connectors
DB	Double Bell
DI	Drop Inlet
EW	Endwall
FL	Flowline of Pipe
INV	Invert (Bottom of Pipe)
MH	Manhole
PVC	Polyvinylchloride Pipe
RCP	Reinforced Concrete Pipe
TP	Top of Pipe
UD	Underdrain
VCP	Vitrified Clay Pipe

IX. RIGHT-OF-WAY & PROPERTY LINES

R/W	Right-of-Way
R/W MON	Right-of-Way Monument
SM	Stone Monument
PL	Property Line
APP PL	Approximate Property Line
IP	Iron Pin

X. UTILITIES

HYD	Hydrant
WM	Water Main
WG	Water Gate
GM	Gas Main
GG	Gas Gate
SM	Sewer Main
SMH	Sewer Manhole

Appendix 2B

STANDARD SYMBOLS

STANDARD SYMBOLS

DESCRIPTION	SYMBOL	
	EXISTING	PROPOSED
EDGE OF TRAVELLED WAY		
EDGE OF PVMNT		
EDGE OF GRAVEL		
CURB: VERTICAL GRANITE		
CURB: MOUNTABLE GRANITE		
CURB: BITUMINOUS		
CURB: CONCRETE		
SURVEY CENTERLINE		
CONSTRUCTION CENTERLINE		
TRAVERSE LINE		
CUT LINE		C C C
FILL LINE		F F F

STANDARD SYMBOLS

DESCRIPTION	SYMBOL	
	EXISTING	PROPOSED
STORM SEWER / UNDERDRAIN		
SANITARY SEWER		
COMBINED SEWER		
WATER MAIN	W	
GAS MAIN	G	
PETROLIUM LINE	P	
UNDERGROUND ELECTRIC CABLE	E	
UNDERGROUND TELEPHONE CABLE	T	
UNDERGROUND TELEVISION CABLE	TV	
CROSS CULVERT	24" CMP	24" CMP
BOX CULVERT	24"X48" BOX	24"X48" BOX
MULTIPLATE	12' MULTI	12' MULTI

If known, the size of a pipe shall be included as part of the symbol. Example:

8"W

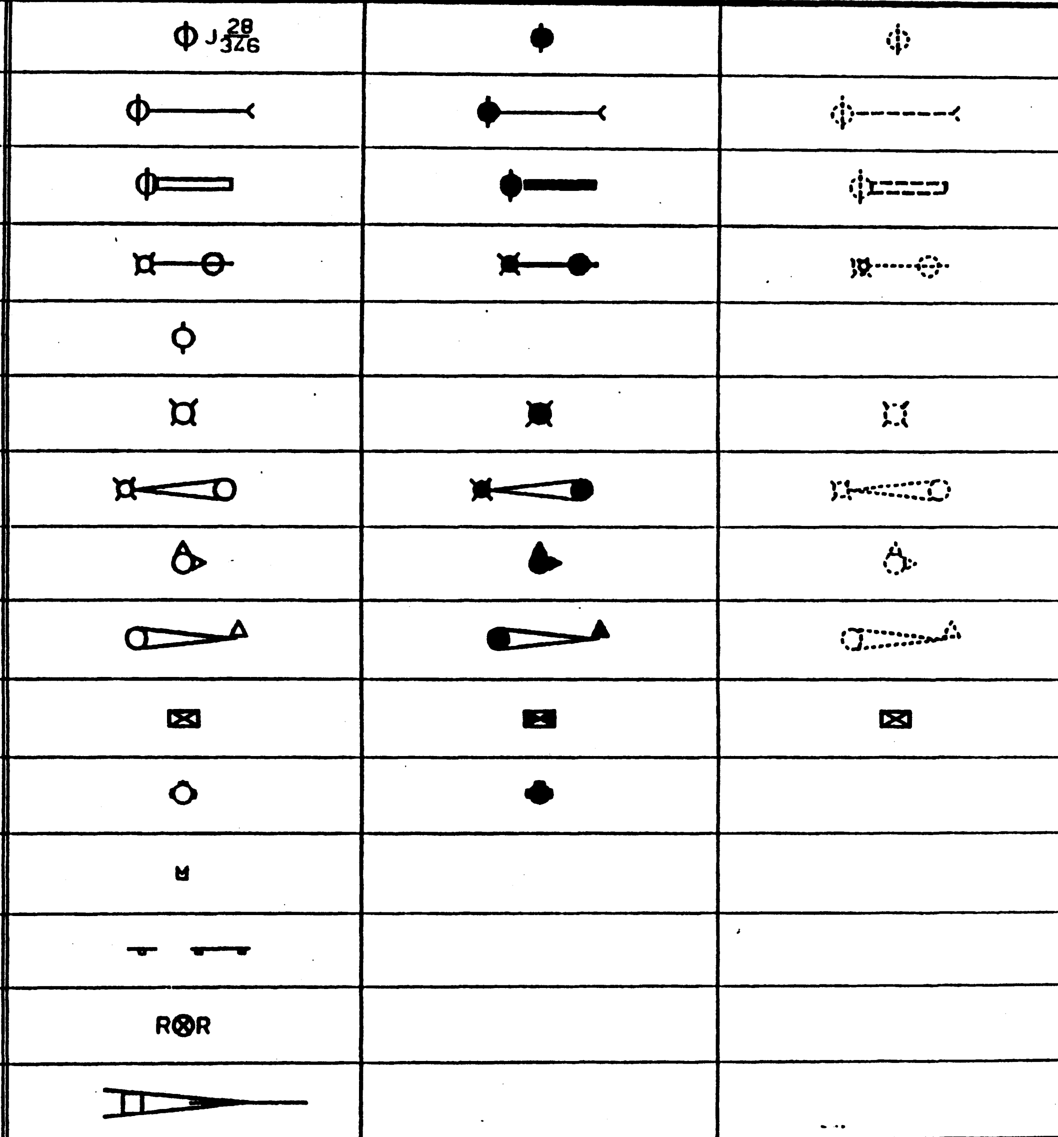
24"

STANDARD SYMBOLS

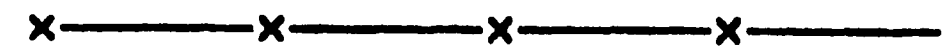
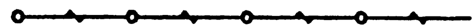
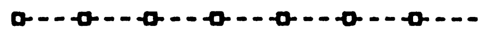
DESCRIPTION	SYMBOL	
	EXISTING	PROPOSED
MANHOLE	⊙	●
CATCH BASIN	▥	■
DROP INLET	▥	
VALVE VAULT, WATER	Ⓥ	
VALVE BOX, WATER OR GAS	⊗	
SERVICE BOX, WATER OR GAS	⊘	
ELECTRICAL VAULT	Ⓔ	
HAND HOLE	⧄	
TELEPHONE VAULT	Ⓣ	
DRILLED WELL	DRILLED WELL ○	
DUG WELL	DUG WELL □	

STANDARD SYMBOLS

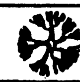
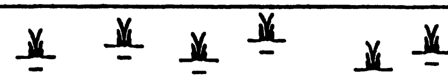
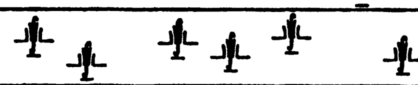
DESCRIPTION	SYMBOL		
	EXISTING	PROPOSED	TEMPORARY
UTILITY POLE (ELEC,TELE,JNT)			
WITH GUY WIRE & ANCHOR			
WITH BRACE (PUSH) POLE			
WITH LIGHT			
STUB POLE			
LIGHT POLE			
WITH MAST ARM			
TRAFFIC SIGNAL			
WITH MAST ARM			
TRAFFIC CONTROL BOX			
FIRE HYDRANT			
MAIL BOX			
SIGN			
RAILROAD SIGNAL			
RAILROAD CROSSING GATE			



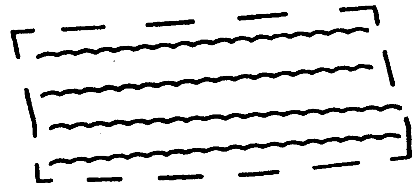
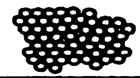
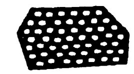
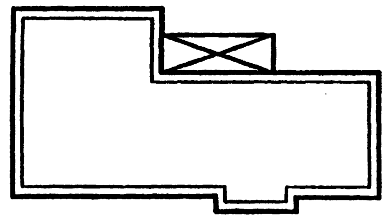
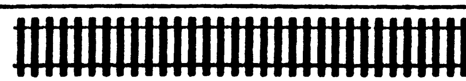
STANDARD SYMBOLS

DESCRIPTION	SYMBOL	
	EXISTING	PROPOSED
FENCE, BARBED WIRE		
FENCE, CHAIN LINK (CYCLONE)		
FENCE, ELECTRIC		
FENCE, WOVEN WIRE (PAGE)		
FENCE, POST & RAIL		
FENCE, STOCKADE		
FENCE, PICKET		
FENCE, RAIL		
WALL, STONE		
WALL, MORTARED STONE		
WALL, BRICK		
WALL, RETAINING OR FOUNDATION		
GUARD RAIL		

STANDARD SYMBOLS

DESCRIPTION	SYMBOL	
	EXISTING	PROPOSED
TREE, DECIDUOUS		
TREE, CONIFEROUS		
TREE, DEAD		
TREE, STUMP	○ STUMP	
BUSH OR SHRUB		
HEDGE ROW		
TREE LINE		
BUSH LINE		
WETLAND, FRESHWATER MARSH		
WETLAND, SALT MARSH		
DITCH		
RUN / BROOK		
CREEK / SMALL STEAM		
SHORELINE OR BANK		

STANDARD SYMBOLS

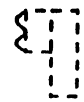
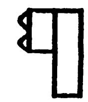
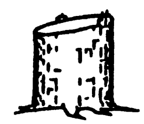
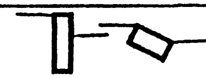
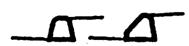
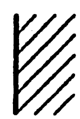
DESCRIPTION	SYMBOL	
	EXISTING	PROPOSED
GARDEN		
RIPRAP		
BUILDING (WITH PORCH)		
FLAG POLE		
MATCH LINE		
PIT		
RAILROAD TRACKS		

NOTE: ALL ANNOTATIONS FOR EXISTING FEATURES SHALL BE DONE WITH "STANDARD" (UPRIGHT) CHARACTERS WHILE NOTES FOR PROPOSED WORK AND ITEMS SHALL BE ITALICIZED.

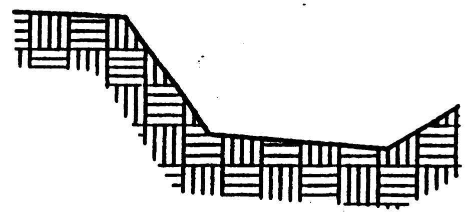
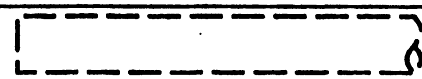
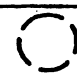
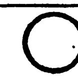
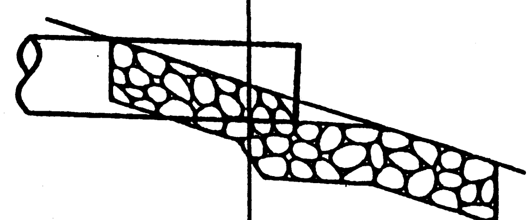
STANDARD SYMBOLS

DESCRIPTION	SYMBOL: EXISTING	SYMBOL: PROPOSED
NATIONAL BOUNDARY		
STATE BOUNDARY		
COUNTY BOUNDARY		
URBAN BOUNDARY		
TOWN BOUNDARY		
RIGHT OF WAY LINE		
PROPERTY LINE		
CONSTRUCTION LIMIT LINE		
GRADING LIMIT LINE		
PROJECT MARKER	P▣M	
SURVEY MARKER	S▣M	
RIGHT OF WAY MARKER	▣	
IRON PIPE (PIN)	● IP	

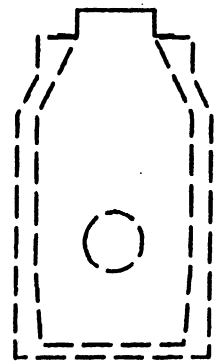
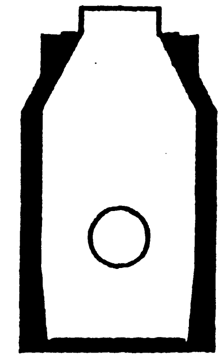
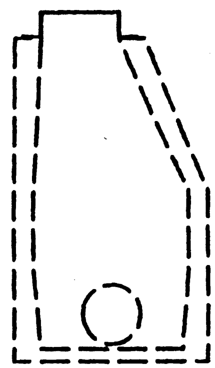
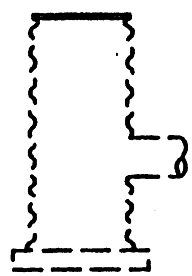
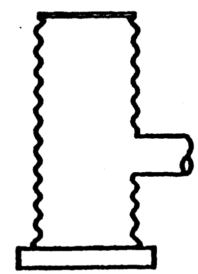
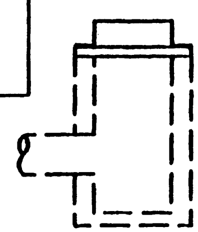
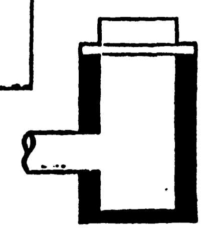
STANDARD SYMBOLS

DESCRIPTION	SYMBOL	
	EXISTING	PROPOSED
UTILITY POLE (ALL TYPES: INCLUDE POLE NUMBER AND OWNER IF KNOWN)		
GUARD RAIL (TYPE 3)		
TREE (NOTE SIZE AND TYPE)		
GRANITE CURB		
BITUMINOUS CURB		
EDGE OF TRAVELLED WAY	X	
BUILDING		

STANDARD SYMBOLS

DESCRIPTION	SYMBOL	
	EXISTING	PROPOSED
GROUND LINE		
LEDGE LINE		
SOIL BORING - REFUSAL	 	
CULVERT (WITH BREAK)		
CULVERT (IN CROSS SECTION)		
CONCRETE PAVEMENT		
EX. CONC. PVT. TO BE REMOVED		
RIPRAP (STONE DITCH, ETC.)		

STANDARD SYMBOLS

DESCRIPTION	SYMBOL	
	EXISTING	PROPOSED
CATCH BASIN		
MANHOLE OR CATCH BASIN WITH ECCENTRIC CONE		
CATCH BASIN TYPE E		
CATCH BASIN TYPE F		

Appendix 2C

EARTHWORK COMPUTATION WORKSHEET

(Form HD-EC)

EARTHWORK COMPUTATION WORKSHEET
(Form HD-EC)

COMMON EXCAVATION FOR ESTIMATE

COMMON EXCAVATION (FROM CROSS SECTIONS) ________
EARTH FROM DRIVES, OLD ROAD, ETC. ________
GRUBBING IN FILL ________
LOAM SALVAGE IN FILL ________
UNDERCUT ________
MUCK EXCAVATION ________
CULVERT INLET AND OUTLET DITCHES ________
PAVEMENT SALVAGE IN FILL ________
TOTAL COMMON EXCAVATION ________

FILL FOR BORROW CALCULATIONS

COMMON FILL (FROM CROSS SECTIONS) ________
FILL FOR DRIVES ________
GRUBBING IN FILL ________
LOAM SALVAGE IN FILL ________
UNDERCUT ________
MUCK EXCAVATION ________
PAVEMENT SALVAGE IN FILL ________
TOTAL FILL ________

ROCK EXCAVATION FOR ESTIMATE

ROCK EXCAVATION (FROM CROSS SECTIONS) ________
ROCK EXCAVATION (BOULDERS) ________
TOTAL ROCK EXCAVATION ________

UNCLASSIFIED EXCAVATION FOR ESTIMATE

TOTAL UNCLASSIFIED EXCAVATION ________

AVAILABLE COMMON EXCAVATION FOR BORROW CALCULATIONS

(1) TOTAL COMMON EXCAVATION ________
DEDUCTIONS:
GRUBBING IN CUT ________
GRUBBING IN FILL ________
LOAM SALVAGE IN CUT ________
LOAM SALVAGE IN FILL ________
UNDERCUT ________
MUCK EXCAVATION ________
PAVEMENT SALVAGE (CUT & FILL) ________

(2) TOTAL DEDUCTIONS ____________

TOTAL AVAILABLE COMMON EXCAVATION (1) MINUS (2) ____________

TOTAL AVAILABLE STRUCT. EXCAVATIONS (USUALLY UNDERDRAIN ONLY) ____________

TOTAL AVAILABLE NON-ROCK EXCAVATION ____________

COMPUTATION OF WASTE STORAGE & WASTE MATERIAL

TOTAL AVAIL. WASTE STORAGE AREA (FROM CROSS SECTIONS) ____________

GRUBBING IN CUT ____________

GRUBBING IN FILL ____________

UNDERCUT ____________

MUCK EXCAVATION ____________

TOTAL WASTE MATERIAL TO BE UTILIZED (LOWER OF TOTAL AVAILABLE WASTE STORAGE AREA OR TOTAL WASTE MATERIAL) ____________

TOTAL WASTE MATERIAL TO BE WASTED (TOTAL WASTE MATERIAL MINUS TOTAL WASTE MATERIAL TO BE UTILIZED) ____________

COMPUTATION OF GRANULAR BORROW FOR ESTIMATE

GRANULAR BORROW TO REPLACE MUCK ____________

GRANULAR BORROW IN LOW WET AREAS ____________

GRANULAR BORROW TO UPGRADE EXCAVATION ____________

GRANULAR BORROW TO MAINTAIN TRAFFIC ____________

GRANULAR BORROW FOR UNDERCUTTING ____________

GRANULAR BORROW = ____________ x 1.15= ____________

COMPUTATION FOR COMMON BORROW FOR ESTIMATE

(3)TOTAL FILL ____________

TOTAL AVAIL. NON-ROCK EXCAV.	____________	x 0.85 =	____________	
TOTAL AVAIL. ROCK EXCAV.	____________	x 1.33 =	____________	
TOTAL AVAIL. STR. ROCK EXCAV.	____________	x 1.33 =	____________	
TOTAL WASTE MATERIAL TO BE UTILIZED	____________	x 1 =	____________	
(4)TOTAL AVAILABLE EXCAVATION			=	____________
BORROW NEEDED = TOTAL FILL MINUS TOTAL AVAILABLE EXCAVATION				____________

IF NO BORROW IS NEEDED, SURPLUS MATERIAL = AVAILABLE EXCAVATION MINUS TOTAL FILL, PLUS TOTAL WASTE MATERIAL TO BE WASTED ____________

GRANULAR BORROW IN LOW WET AREAS		______
GRANULAR BORROW TO UPGRADE EXCAVATION		______
GRANULAR BORROW TO MAINTAIN TRAFFIC		______
TOTAL FILL MINUS REQUIRED GRAN. BORR. WITHIN FILL		______
COMMON BORROW =	______ x 1.15 =	______

Appendix 2E

CONSTRUCTION NOTES

CONSTRUCTION NOTES

The chart on the following page lists some of the more common design features that would typically require construction notes and labeling on a project and where they would be found in the plan set. Every possible construction note that might be needed on a project is not listed here. Judgment is needed. All work should be noted either in construction notes or general notes as to how it will be paid for – either with specific pay items or work to be incidental to certain pay items or the contract.

Generally the type of information required would be:

- Location (stations and offsets as needed)
- Description of work
- Pay item (if applicable)
- Quantity (in some cases)

Examples showing formats and information needed in some commonly used construction notes may be found on the sample plan and cross section sheets in Appendix 2H.

Additional information on construction notes is scattered throughout Chapter Fourteen of the MaineDOT Highway Design Guide.

Proposed construction action and feature	Plan / Profile Sheet	Cross Sections	Construction Note Sheet (if needed)
Begin / End Project	*Show, label*	*Note*	
Approaches	*Show, label*	*Note*	
Clearing	*Show, label and note*		*Note*
Remove Single tree	*Label, note*	*Label remove*	*Note*
Removing stump	*Label, note*	*Label remove*	*Note*
Building removal	*Label, note*		*Note*
Drives and Entrances Paved Gravel Field / Woods Entrances Grass Ent Curb Openings Crushed Stone Entrances	*Show and Note*	*Show and Note*	*Note*
Paved / Concrete Walk	*Show and Note*	*Show and Note*	*Note*
Proposed Drainage Items Roadway Culverts Driveway culverts Underdrain Pipes Catch Basins and Manholes	*Show and label*	*Show and Note*	*Note*
Removing Manhole or catch basin	*Label "remove" and note*	*Label "remove"*	*Note*
Grubbing in Fill	*Note*	*Show and note*	*Note*
Topsoil Salvage	*Note*	*Show and note*	*Note*
Benching	*Note*	*Show and note*	*Note*
Muck Excavation		*Show and note*	
Guard Rail items	*Show and note*	*Show and note*	*Note*
Fencing – Proposed and Reset Remove	*Note* *Label "Remove"*	*Note*	*Note*
Pedestrian Ramps	*Note and show*	*Note*	*Note*
Truncated Domes	*Note*		*Note*
Curbing [2,3]	*Show and Note*	*Show*	*Note*
RipRap Culvert end protection Riprap Aprons	*Show* and note*	*Show[1] and note*	*Note*
Stone Ditch Protection	*Note*	*Note*	*Note*
Erosion Control Blanket	*Note*	*Note*	*Note*
Downspouts	*Show[1] and note*	*Show[1] and note*	*Note*
Retaining walls	*Show and note*	*Show and note*	*Note*
Seeding method [5]	*Note*		*Note*
Landscaping items	*Show and note[4]*		*Note[4]*
Concrete steps	*Note*	*Show and note*	*Note*
Ditching	*Show*	*Show and Note*	

1 if practical

2 On projects requiring geometric and curb layout sheets with extensive curb notes the curb notes may be placed on either the geometric sheets or separate curb note sheet

3. If more than one type of curb mold is used on a project the construction notes should specify the stationing for each mold

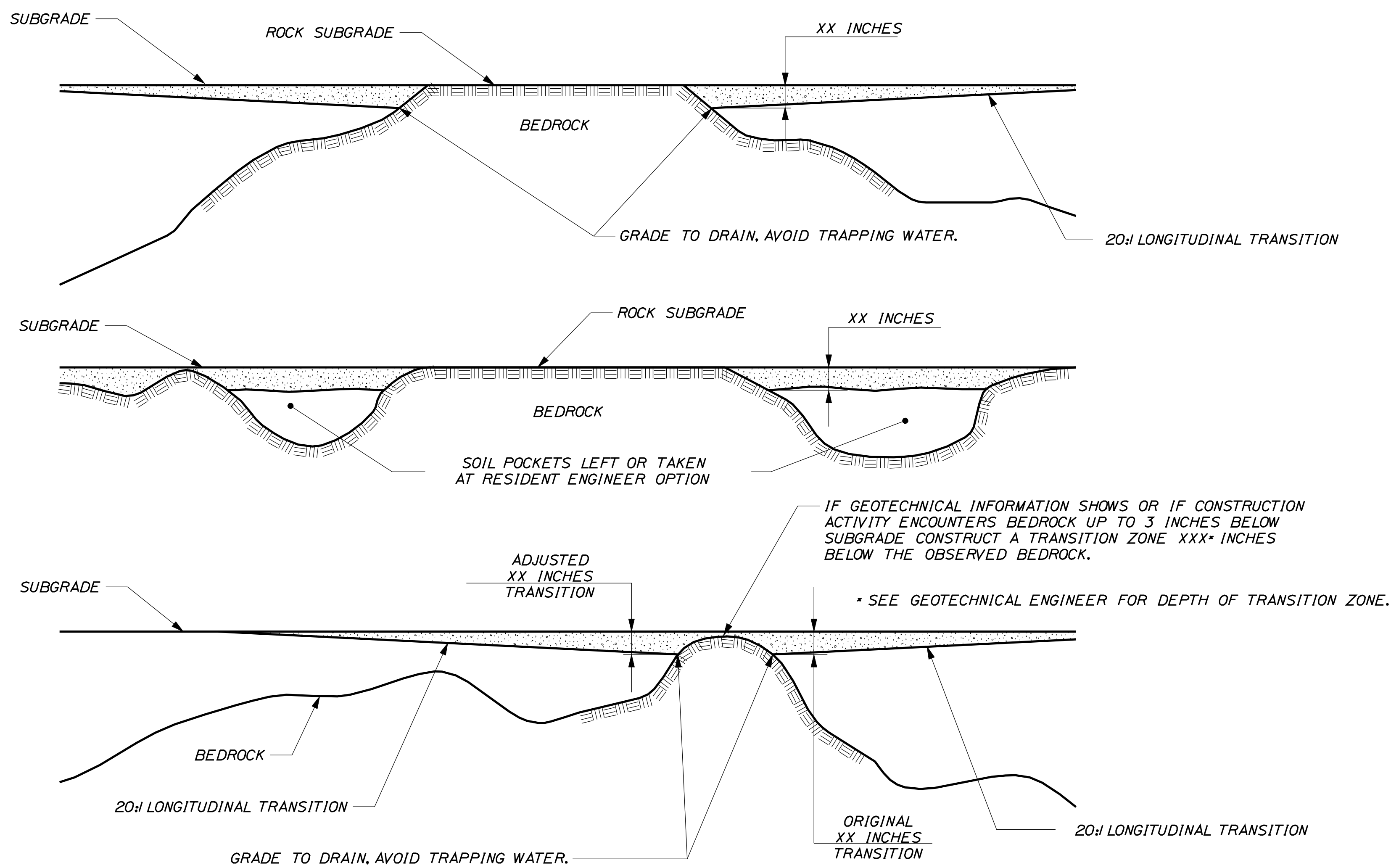
4 Landscaping may be included in the project as a separate plan set instead of showing on the highway construction plan sheets

5 General Note may be used instead of construction note

Appendix 2F

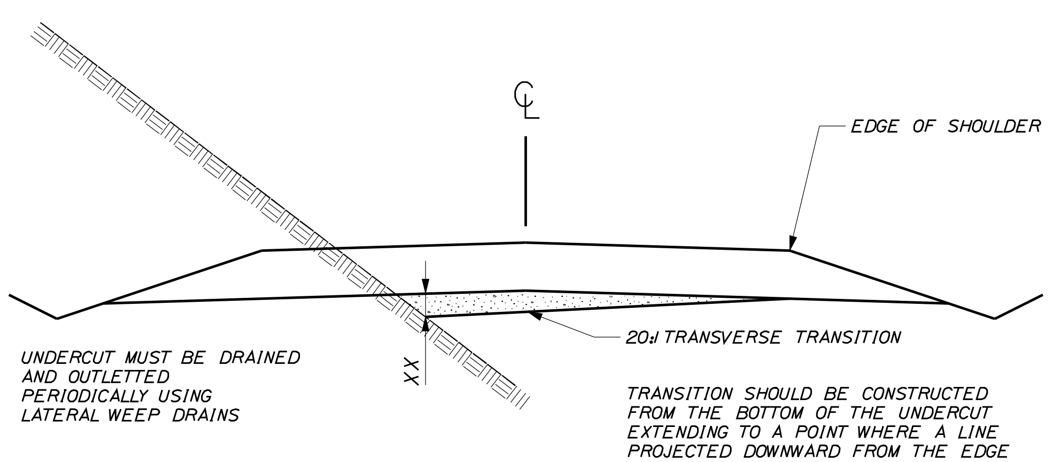
SPECIAL DETAILS

PROFILE OF UNDERCUT OF FROST SUSCEPTIBLE SOILS OVER LEDGE



IF A SOIL SECTION BETWEEN LEDGE SUBGRADE IS OF SUCH LENGTH THAT THE TRANSITION FROM EACH EDGE WOULD MEET. IT SHOULD BE TREATED AS AN EARTH POCKET

TRANSVERSE UNDERCUT OF FROST SUSCEPTIBLE SOILS OVER LEDGE

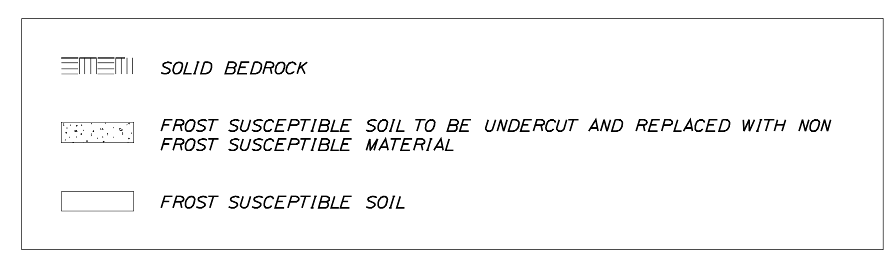


NOTES:

1. EXCAVATION OF THE TRANSITION ZONES SHALL BE PAID FOR AS COMMON EXCAVATION. THE CONTRACTOR SHALL REPLACE THE FROST SUSCEPTIBLE SOILS WITH GRAVEL BORROW AND SHALL BE PAID FOR UNDER THE GRAVEL BORROW PAY ITEM.
2. FOR POTENTIAL BEDROCK LOCATIONS, REFER TO THE BORING LOG SHEETS AND CROSS SECTIONS. ACTUAL BEDROCK LOCATIONS WILL VARY.
3. REFER TO MAINEDOT SOILS REPORT ______ FOR ADDITIONAL TRANSITION ZONE DETAILS.
4. APPROXIMATE ANTICIPATED AREAS OF LEDGE TRANSITIONS ARE LISTED BELOW:

   XX+XX TO XX+XX
   XX+XX TO XX+XX
   XX+XX TO XX+XX
   XX+XX TO XX+XX

   ADDITIONAL AREAS OF LEDGE MAY BE ENCOUNTERED AND THE NEED FOR UNDERCUT SHOULD BE VERIFIED BY THE RESIDENT



STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-0000(000)X

PIN 00000.00

HIGHWAY PLANS

	E.M.	BY	DATE
PROJ. MANAGER			
DESIGN-DETAILED	M.M.	M.R.P.	3-5-2007
CHECKED-REVIEWED			
DESIGN2-DETAILED2		M.B.	
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

DATE

TOWN
ROUTE

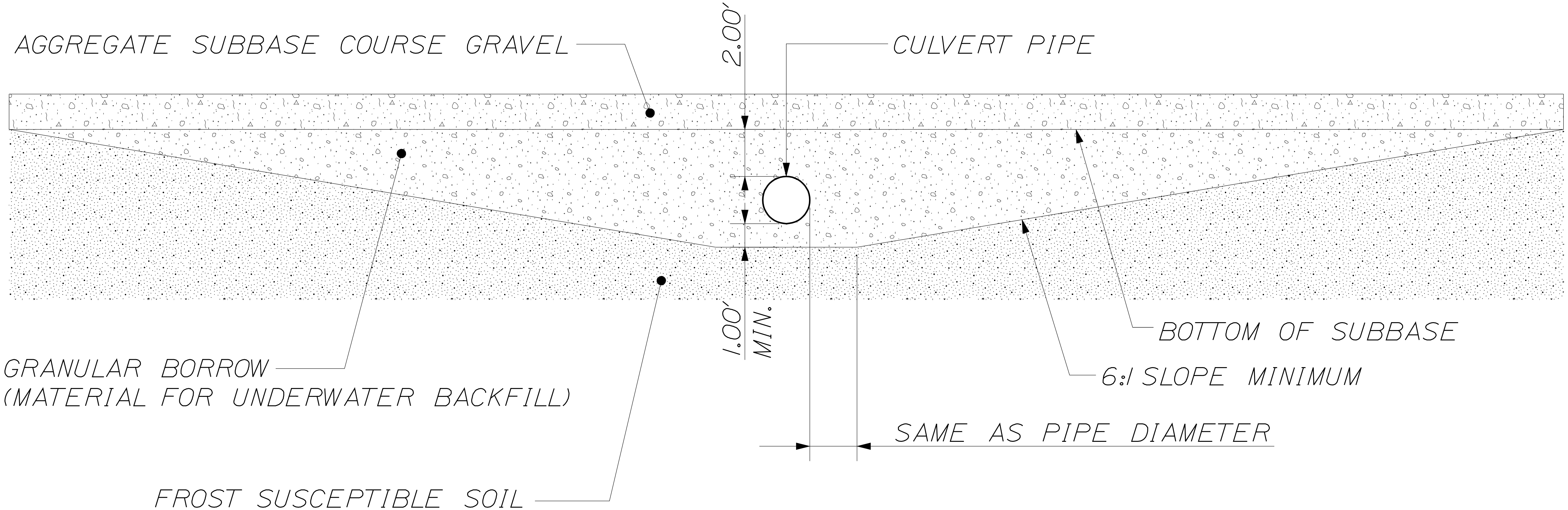
SPECIAL DETAILS

SHEET NUMBER

OF

Filename: k:\chapter 2\SD_LEDGE_CUT.dgn Division: HIGHWAY Username: jonathan.french Date:12/19/2007

CROSS CULVERT IN FROST SUSCEPTIBLE SOILS



STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-0000(000)X

PIN 00000.00

HIGHWAY PLANS

		BY	DATE
PROJ. MANAGER	E.M.		
DESIGN-DETAILED	M.M.	M.R.P.	3-5-2007
CHECKED-REVIEWED			
DESIGN2-DETAILED2		M.B.	
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

DATE

TOWN
ROUTE

SPECIAL DETAILS

SHEET NUMBER

OF

Filename: ...\chapter 2\SD_FrostCulvert.dgn Division: HIGHWAY Username: jonathan.french Date:12/19/2007

Appendix 2G

FONTS

U.S. Customary Font Table

Drawing Type	Type	Font	Height	Width	Line Spacing	Slant*	Sample
US 22x34 Pages (12"=1')							
Title Sheet:	Text Note**	123 dotitalics	0.01	0.0113	0.0067	16.88º	SAMPLE
	Title Text	123 dotitalics	0.0146	0.0165	0.0097	16.88º	SAMPLE
	Title Text (Underlined)	123 dotitalics	0.0146	0.0165	0.0097	16.88º	SAMPLE
	Existing Text	32 dot_eng	0.01	0.01	0.0067	0º	SAMPLE
Estimated Quantities	Monospaced Text	3 engineering	0.01	0.01	0.0067	0º	SAMPLE
	Text Note**	123 dotitalics	0.01	0.0113	0.0067	16.88º	SAMPLE
Drainage Sheet	Text Note**	123 dotitalics	0.01	0.0113	0.0067	16.88º	SAMPLE
General Notes	Text Note**	123 dotitalics	0.01	0.0113	0.0067	16.88º	SAMPLE
	Title Text (Underlined)	123 dotitalics	0.0146	0.0165	0.0097	16.88º	SAMPLE
Construction Notes	Monospaced Text	3 engineering	0.01	0.01	0.0067	0º	SAMPLE
	Text Note**	123 dotitalics	0.01	0.0113	0.0067	16.88º	SAMPLE
	Title Text	123 dotitalics	0.0146	0.0165	0.0097	16.88º	SAMPLE
	Title Text (Underlined)	123 dotitalics	0.0146	0.0165	0.0097	16.88º	SAMPLE
US Typicals 1"=4' (1:48)							
Typicals, Special Details	Monospaced Text	3 engineering	0.48	0.48	0.32	0º	SAMPLE
	Text Note**	123 dotitalics	0.48	0.544	0.32	16.88º	SAMPLE
	Title Text	123 dotitalics	0.7	0.7932	0.4668	16.88º	SAMPLE
	Title Text (Underlined)	123 dotitalics	0.7	0.7932	0.4668	16.88º	SAMPLE
	Sub-Title Text	123 dotitalics	0.56	0.6348	0.3732	16.88º	SAMPLE
US Plan 1"=25' (1:300)							
Plan/Profile	Monospaced Text	3 engineering	3	3	2	0º	SAMPLE
	Text Note**	123 dotitalics	3	3.4	2	16.88º	SAMPLE
	Text Note (Underlined)**	123 dotitalics	3	3.4	2	16.88º	SAMPLE
	Existing Text	32 dot_eng	3	3.4	2	0º	SAMPLE
Geometrics	Monospaced Text	3 engineering	3	3	2	0º	SAMPLE
	Text Note	123 dotitalics	3	3.4	2	16.88º	SAMPLE
US Plan 1"=50' (1:600)							
Plan/Profile	Monospaced Text	3 engineering	6	6	4	0º	SAMPLE
	Text Note**	123 dotitalics	6	6.8	4	16.88º	SAMPLE
	Text Note (Underlined)**	123 dotitalics	6	6.8	4	16.88º	SAMPLE
	Existing Text	32 dot_eng	6	6	4	0º	SAMPLE
Geometrics	Monospaced Text	3 engineering	6	6	4	0º	SAMPLE
	Text Note	123 dotitalics	6	6.8	4	16.88º	SAMPLE
US Sections 1"=5' (1:60)							
Cross Section Sheets	Monospaced Text	3 engineering	0.6	0.6	0.4	0º	SAMPLE
	Text Note**	123 dotitalics	0.6	0.68	0.4	16.88º	SAMPLE
	Title Text	123 dotitalics	0.875	0.9915	0.5835	16.88º	SAMPLE
	Title Text (Underlined)	123 dotitalics	0.875	0.9915	0.5835	16.88º	SAMPLE
	Sub-Title Text	123 dotitalics	0.7	0.7935	0.4665	16.88º	SAMPLE
	Existing Text	32 dot_eng	0.6	0.6	0.4	0º	SAMPLE
US Sections 1"=10' (1:120)							
Cross Section Sheets	Monospaced Text	3 engineering	1.2	1.2	0.8	0º	SAMPLE
	Text Note**	123 dotitalics	1.2	1.36	0.8	16.88º	SAMPLE
	Title Text	123 dotitalics	1.75	1.983	1.167	16.88º	SAMPLE
	Title Text (Underlined)	123 dotitalics	1.75	1.983	1.167	16.88º	SAMPLE
	Sub-Title Text	123 dotitalics	1.4	1.587	0.933	16.88º	SAMPLE
	Existing Text	32 dot_eng	1.2	1.2	0.8	0º	SAMPLE

* The custom font "123 dotitalics" has a slant built into the font, therefore a "0" slant is applied. The slant is only displayed here for those trying to reproduce the custom font.

** "Text Note" and "Text Note (Underlined)" is the same style as "Standard Text" and "Standard Text (Underlined)" for the MaineDOT MicroStation platform

Appendix 2H

SAMPLE SHEETS

Figure 2-1

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

PLAN LEGEND

Town, County, State		Centerline-Existing	
Property Lines		Centerline-Proposed	10+00
R/W Lines-Existing		Travelway-Existing	
R/W Lines-Proposed		Travelway-Proposed	
Culvert-Existing		Railroad	
Culvert Proposed		Catch Basins	Existing ■ Proposed
Curbing	Existing / Proposed	Manholes	Existing ● Proposed
Type 1		Proposed Underdrain	
Type 3		Proposed Ditch	
Type 5		Existing Ditch	
Outline of Bodies of Water		Utlity Poles	Existing ♦ Proposed
Ledge		Fire Hydrants	Existing Proposed
Buildings		Existing Water Line	
Trees	Conifer / Deciduous	Existing San. Sewer	
Tree Line		Existing San. Sewer Manhole	
Clearing Limit Line	CLL	Guardrail-Existing	
		Guardrail-Proposed	
		Guardrail-Cable, Other	

CHESTERVILLE - FARMINGTON

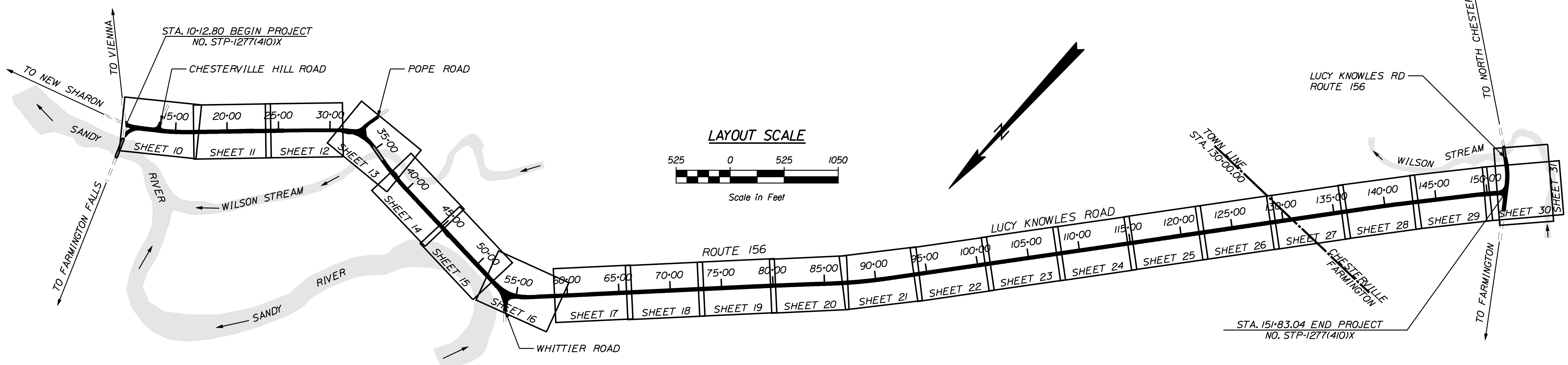
FRANKLIN COUNTY

ROUTE 156

STP-1277(410)X

PROJECT LENGTH: 2.81 MILES

INDEX OF SHEETS



TRAFFIC DATA

	SR 156 AT WILTON-CHESTERVILLE TOWNLINE	SR 156 NW/O IR 430 @ BRIDGE #2273 @ TL
Current (2010) AADT	1970	4070
Future (2030) AADT	2760	5700
DHV - % of AADT	11%	11%
Design Hour Volume	304	627
% Heavy Trucks (AADT)	11%	11%
% Heavy Trucks (DHV)	8%	8%
Directional Distribution (DHV)	60%	60%
18 kip Equivalent P 2.0	239	393
18 kip Equivalent P 2.5	228	374
Design Speed (mph)	30,35,50 MPH	30 MPH
Functional Class	Major Collector	Major Collector

PROJECT LOCATION:	Rte. 156 from the intersection of Rte. 41 extending 2.81 miles westerly to Wilson Stream Bridge at the Chesterville/Farmington town line.
PROGRAM AREA:	Highway Program
SCOPE OF WORK:	Highway Rehabilitation with Safety and Drainage Improvements

WIN 12774.10 STP-1277(410)X

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

APPROVED	DATE
COMMISSIONER:	
CHIEF ENGINEER:	

PROJECT INFORMATION	SIGNATURE	P.E. NUMBER	DATE
HIGHWAY			
PROGRAM			
PROJECT MANAGER			
DESIGNER			
DESIGNER			
PROJECT RESIDENT			
CONTRACTOR			
PROJECT COMPLETION DATE			

CHESTERVILLE - FARMINGTON
RTE. 156

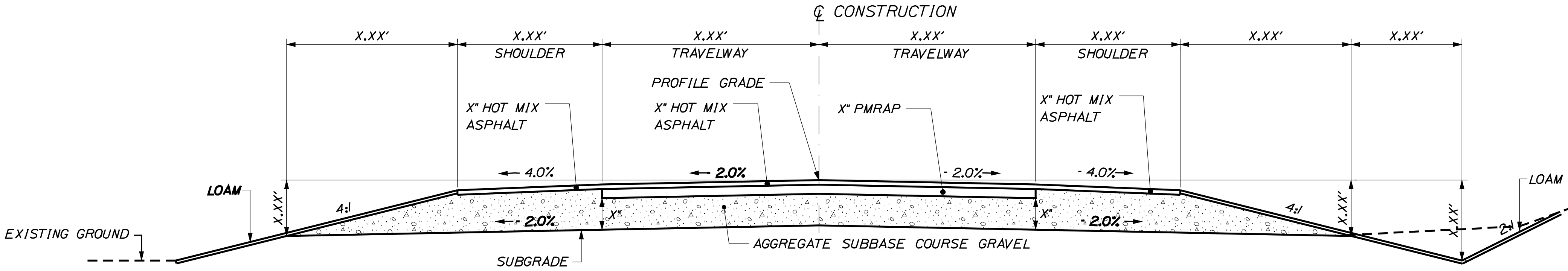
TITLE SHEET

SHEET NUMBER

1

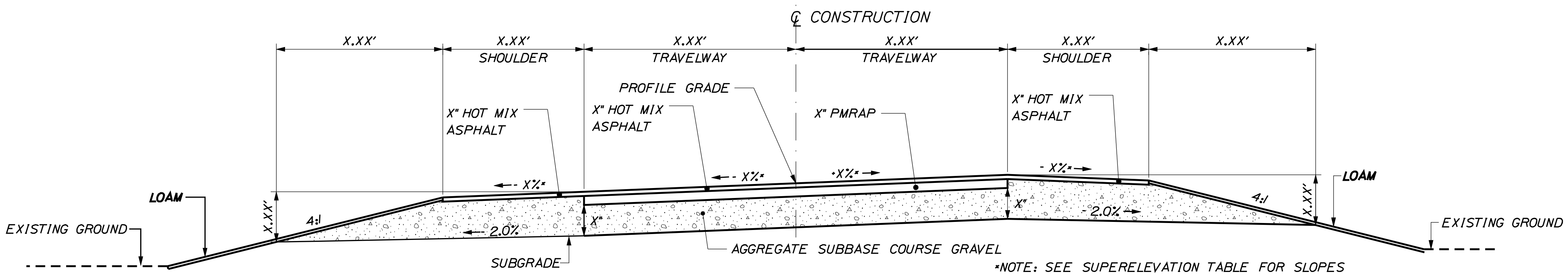
OF 188

Filename: ...\2011 New Title Sheet Format.dgn Division: HIGHWAY Username: jonathon.french Date:8/3/2011



AGGREGATE SUBBASE COURSE GRAVEL		
LEFT SHOULDER X CY/100 LF	X FT. TRAVEL LANES X CY/100 LF	RIGHT SHOULDER X CY/100 LF
STATION TO STATION	STATION TO STATION	STATION TO STATION
0+00 to 0+00 LT.	0+00 to 0+00	0+00 to 0+00 LT.
0+00 to 0+00 RT.		0+00 to 0+00 RT.
0+00 to 0+00 RT.		0+00 to 0+00 RT.

FULL CONSTRUCTION
NORMAL



AGGREGATE SUBBASE COURSE GRAVEL		
LOW SIDE SUPERELEVATED SHOULDER X CY/100 LF	X FT. TRAVEL LANES X CY/100 LF	HIGH SIDE SUPERELEVATED SHOULDER X CY/100 LF
STATION TO STATION	STATION TO STATION	STATION TO STATION
0+00 to 0+00 LT.	0+00 to 0+00	0+00 to 0+00 LT.
0+00 to 0+00 RT.		0+00 to 0+00 RT.
0+00 to 0+00 RT.		0+00 to 0+00 RT.

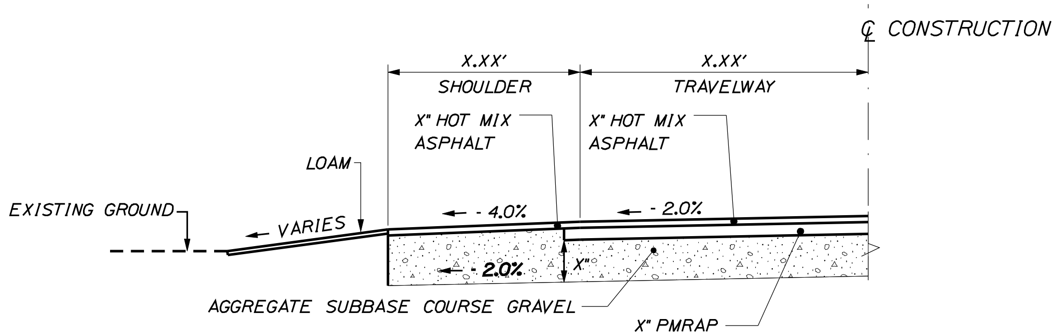
FULL CONSTRUCTION
SUPERELEVATED

NOTE:

1. THE PAVEMENT, BASE AND SUBBASE DEPTHS AS SHOWN ON THE PLANS ARE INTENDED TO BE NOMINAL.
2. WHEN SUPERELEVATION EXCEEDS THE SLOPE OF THE LOW SIDE SHOULDER, THE LOW SIDE SHOULDER SHALL HAVE THE SAME SLOPE AS THE TRAVELWAY.
3. CROWNS FOR BOTH NORMAL AND SUPERELEVATION SECTIONS FOR ALL COURSES OF SUBBASE AND PAVEMENT SHALL BE STRAIGHT
4. THE GRAVEL QUANTITY CALCULATION IS BASED ON A 2' LOAM OR DIRTY BORROW DEPTH. THE ACTUAL DEPTH MAY VARY. SEE THE GENERAL NOTES.
5. THE ALGEBRAIC DIFFERENCE BETWEEN THE SHOULDER AND TRAVEWAY CROSS SLOPES "ROLLOVER" SHALL NOT EXCEED 8%.
6. THE STATIONING SHOWN UNDER EACH TYPICAL IS APPROXIMATE.

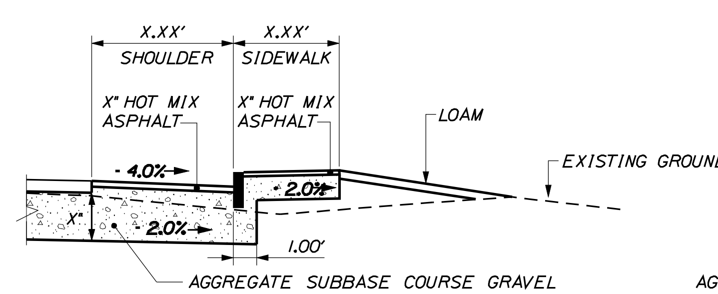
SUPERELEVATION TABLE

LT. SHOULDER	LT. TRAVELWAY	STATION	RT. TRAVELWAY	RT. SHOULDER
		START		
-6.0	**-3.0**	**1+00**	**-3.0**	**-6.0**
-4.0	-2.9	1+25	-2.1	-6.0
-4.0	-2.8	1+50	-1.2	-6.0
-4.0	-2.8	1+75	-0.3	-6.0
-4.0	-2.7	2+00	0.7	-6.0
-4.0	-2.6	2+25	1.6	-6.0
-6.0	-2.5	2+50	2.5	-5.5
		TO		
-6.0	-2.5	4+50	2.5	-5.5
-6.0	-2.6	4+75	1.9	-6.0
-6.0	-2.6	5+00	1.3	-6.0
-6.0	-2.7	5+25	0.7	-6.0
-6.0	-2.7	5+50	0.1	-6.0
-6.0	-2.8	5+75	-0.6	-6.0
-6.0	-2.8	6+00	-1.2	-6.0
-6.0	-2.9	6+25	-1.8	-6.0
-6.0	-2.9	6+50	-2.4	-6.0
-6.0	**-3.0**	**6+75**	**-3.0**	**-6.0**
		END		



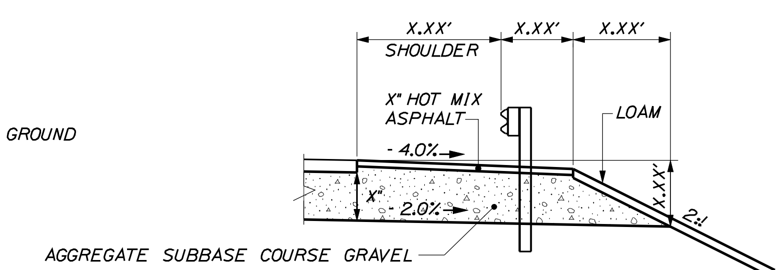
AGGREGATE SUBBASE COURSE GRAVEL
SHOULDER
X CY/100 LF
STATION TO STATION
0+00 to 0+00 LT.
0+00 to 0+00 RT.
0+00 to 0+00 LT.

BOX SHOULDER



AGGREGATE SUBBASE COURSE GRAVEL
SHOULDER
X CY/100 LF
STATION TO STATION
0+00 to 0+00 LT.
0+00 to 0+00 RT.
0+00 to 0+00 LT.

CURB TYPE 1 W/SIDEWALK



AGGREGATE SUBBASE COURSE GRAVEL
SHOULDER
X CY/100 LF
STATION TO STATION
0+00 to 0+00 LT.
0+00 to 0+00 RT.
0+00 to 0+00 LT.

GUARDRAIL TYPE 3C

NOT TO SCALE

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-0000(000)X

PIN 00000.00

HIGHWAY PLANS

SIGNATURE

P.E. NUMBER

DATE

DATE

BY

PROJ. MANAGER $PROJMANAGER$
DESIGN-DETAILED
CHECKED-REVIEWED
DESIGN2-DETAILED2
DESIGN3-DETAILED3
REVISIONS 1
REVISIONS 2
REVISIONS 3
REVISIONS 4
FIELD CHANGES

TOWN
ROUTE

TYPICAL SECTIONS

SHEET NUMBER

2

OF 10

Filename: K:\Chapter 2\002_Typical.dgn Division: HIGHWAY Username: jonathan.french Date:12/19/2007

Figure 2-3

ESTIMATED QUANTITIES			
ITEM NO.	DESCRIPTION	QUANTITY	UNIT
201.11	CLEARING	2.03	AC
201.23	REMOVING SINGLE TREE TOP ONLY	8	EA
201.24	REMOVING STUMP	9	EA
203.20	COMMON EXCAVATION	35733	CY
203.21	ROCK EXCAVATION	463	CY
203.24	COMMON BORROW	27513	CY
203.25	GRANULAR BORROW	3141	CY
* 206.061	STR EARTH BELOW GRADE STR	65	CY
206.07	STR ROCK EXC - DR & MINOR STR	46	CY
304.10	AGGR SUBB COURSE - GRAVEL	22775	CY
309.36	FULL DEPTH RECYCLED PVMT W/ FOAM ASPHALT 6 INCH DEPTH	42435	SY
403.208	HOT MIX ASPHALT 0.5 IN. SURFACE	3660	TON
403.209	HOT MIX ASPHALT 0.4 IN (INCID)	20	TON
403.213	HOT MIX ASPHALT 0.5 IN. BASE	5281	TON
409.15	BITUMINOUS TACK COAT APPLIED	1519	GAL
603.16	15 IN CULVERT PIPE OPTION I	477	FT
603.17	18 IN CULVERT PIPE OPTION I	329	FT
603.175	18 IN RCP CLASS III	86	FT
603.179	18 IN CULVERT PIPE OPTION III	69	FT
603.19	24 IN CULVERT PIPE OPTION I	105	FT
603.199	24 IN CULVERT PIPE OPTION III	326	FT
603.209	30 IN CULVERT PIPE OPTION III	151	FT
603.41	24 IN RCP CLASS IV	99	FT
603.45	48 IN RCP CLASS IV	171	FT
605.09	6 IN UNDERDRAIN TYPE B	1845	FT
605.10	6 IN UNDERDRAIN OUTLET	214	FT
606.23	GR TY 3C - SINGLE RAIL	780	FT
606.35	GR DELINEATOR POST	10	EA
606.79	GUARDRAIL 350 FLARED TERMINAL	4	EA
607.24	REMOVE AND RESET FENCE	33	FT
609.31	CURB TYPE 3	283	FT
610.08	PLAIN RIPRAP	131	CY
610.18	STONE DITCH PROTECTION	484	CY
612.06	BITUMINOUS SEALING - BLACK	36	SY
613.319	EROSION CONTROL BLANKET	6818	SY
615.07	LOAM	3678	CY
618.1301	SEEDING METHOD NUMBER 1 - PLAN QUANTITY	110	UN
618.1401	SEEDING METHOD NUMBER 2 - PLAN QUANTITY	310	UN
618.1411	SEEDING METHOD NUMBER 3 - PLAN QUANTITY	110	UN
619.1201	MULCH - PLAN QUANTITY	540	UN
* 619.1401	EROSION CONTROL MIX	131	CY
620.58	EROSION CONTROL GEOTEXTILE	1794	SY
* 621.031	EVERGREEN TR (4 FT - 5 FT) GP A	6	EA
* 621.037	EVERGREEN TR (5 FT - 6 FT) GP A	42	EA
* 621.195	MD DECID TR (1 3/4 IN - 2 IN) GP A	3	EA
* 621.267	LG DECID TR (1 3/4 IN - 2 IN CAL) GP A	3	EA
* 621.546	DECID SHRUBS (2 FT - 3 FT) GP A	4	EA
* 621.80	ESTABLISHMENT PERIOD	1	LS
627.711	WHITE OR YELLOW PAINT PVMT MRK LINE (PLAN QUANTITY)	33602	FT
627.76	TEMPORARY PVMT MARK LINE, WHITE OR YELLOW	1	LS
629.05	HAND LABOR, STRAIGHT TIME	5	HR
* 631.10	AIR COMPRESSOR (INC OPERATOR)	10	HR
* 631.11	AIR TOOL (INC OPERATOR)	10	HR
* 631.12	ALL-PURPOSE EXC (INC OPERATOR)	20	HR
* 631.132	SMALL BULLDOZER (INC OPERATOR)	20	HR
* 631.14	GRADER (INC OPERATOR)	10	HR
* 631.172	TRUCK-LARGE (INC OPERATOR)	20	HR
* 631.20	STUMP CHIPPER (INC OPERATOR)	5	HR
637.071	DUST CONTROL	1	LS
639.18	FIELD OFFICE TYPE A	1	EA
639.21	TESTING FACILITIES SOILS	1	LS
652.31	TYPE I BARRICADE	60	EA
652.311	TYPE II BARRICADE	40	EA
652.33	DRUM	80	EA
652.34	CONE	120	EA
652.35	CONSTRUCTION SIGNS	652	SF
652.361	MAINT OF TRAFF CONTROL DEV	180	CD
652.38	FLAGGER	3000	HR
656.75	TEMPORARY SOIL EROSION AND WATER POLLUTION	1	LS
657.24	SEEDING PITS	230	UN
658.20	ACRYLIC LATEX FINISH, GREEN	8	SY
659.10	MOBILIZATION	1	LS
660.21	ON-THE-JOB TRAINING (BID)	2000	HR

* UNDETERMINED LOCATIONS

EARTHWORK SUMMARY

COMMON EXCAVATION FOR ESTIMATE

COMMON EXCAVATION (FROM CROSS SECTIONS)	29,589	
EARTH FROM DRIVES, OLD ROAD, ETC.	740	
GRUBBING IN FILL	2,817	
UNDERCUT	271	
PEAT EXCAVATION	2,275	
** PAVEMENT SALVAGE IN FILL (INCLUDES 75 mm UNDERLYING LAYER FOR FOAMED ASPHALT PROCESS)	3,264 **	
TOTAL COMMON EXCAVATION		38,956

FILL FOR BORROW CALCULATIONS

COMMON FILL (FROM CROSS SECTIONS)	43,331	
FILL FOR DRIVES	774	
GRUBBING IN FILL	2,817	
UNDERCUT	271	
PEAT EXCAVATION	2,275	
PAVEMENT SALVAGE IN FILL (INCLUDES 75 mm UNDERLYING LAYER FOR FOAMED ASPHALT PROCESS)	3,264	
TOTAL FILL		52,732

ROCK EXCAVATION FOR ESTIMATE

ROCK EXCAVATION (FROM CROSS SECTIONS)	463	
TOTAL ROCK EXCAVATION		463

UNCLASSIFIED EXCAVATION FOR ESTIMATE

TOTAL UNCLASSIFIED EXCAVATION		0

AVAILABLE COMMON EXCAVATION FOR BORROW CALCULATIONS

(1) TOTAL COMMON EXCAVATION		38,956
DEDUCTIONS:		
GRUBBING IN CUT		5,991
GRUBBING IN FILL	2,817	
UNDERCUT	271	
PEAT EXCAVATION	2,275	
PAVEMENT SALVAGE (CUT & FILL)	6,696	
(2) TOTAL DEDUCTIONS		18,050
TOTAL AVAILABLE COMMON EXCAVATION (1) MINUS (2)		20,906
TOTAL AVAILABLE STRUCT. EXCAVATIONS (USUALLY UNDERDRAIN ONLY)		518
TOTAL AVAILABLE NON-ROCK EXCAVATION		21,424

COMPUTATION OF WASTE STORAGE & WASTE MATERIAL

TOTAL AVAIL. WASTE STORAGE AREA (FROM CROSS SECTIONS)		9,331
GRUBBING IN CUT	5,991	
GRUBBING IN FILL	2,817	
UNDERCUT	271	
PEAT EXCAVATION	2,275	
TOTAL WASTE MATERIAL TO BE UTILIZED (LOWER OF TOTAL AVAILABLE WASTE STORAGE AREA OR TOTAL WASTE MATERIAL)		11,354
TOTAL WASTE MATERIAL TO BE WASTED (TOTAL WASTE MATERIAL MINUS TOTAL WASTE MATERIAL TO BE UTILIZED)		2,022

COMPUTATION OF GRANULAR BORROW FOR ESTIMATE

GRANULAR BORROW TO REPLACE PEAT	2,277	
GRANULAR BORROW IN LOW WET AREAS	262	
GRANULAR BORROW TO UPGRADE EXCAVATION		
GRANULAR BORROW TO MAINTAIN TRAFFIC	327	
GRANULAR BORROW FOR UNDERCUTTING	275	
GRANULAR BORROW =	3,141 x 1.15 =	3,613

COMPUTATION FOR COMMON BORROW FOR ESTIMATE

(3) TOTAL FILL			52,732
TOTAL AVAIL. NON-ROCK EXCAV.	21,424 x 0.85 =	18,210	
TOTAL AVAIL. ROCK EXCAV.	463 x 1.33 =	616	
TOTAL AVAIL. STR. ROCK EXCAV.	46 x 1.33 =	62	
TOTAL WASTE MATERIAL TO BE UTILIZED	9,331 x 1 =	9,331	
(4) TOTAL AVAILABLE EXCAVATION	=		28,219
BORROW NEEDED = TOTAL FILL MINUS TOTAL AVAILABLE EXCAVATION			24,512
GRANULAR BORROW IN LOW WET AREAS			262
GRANULAR BORROW TO UPGRADE EXCAVATION			0
GRANULAR BORROW TO MAINTAIN TRAFFIC			327
TOTAL FILL MINUS REQUIRED GRAN. BORR. WITHIN FILL			23,923
COMMON BORROW =	18,277 x 1.15 =		27,512

** PAVEMENT SALVAGE IN FILL IS NOT INCLUDED IN THE COMMON EXCAVATION QUANTITY FOR PAYMENT. PAYMENT FOR PAVEMENT SALVAGE IN FILL IS INCIDENTAL TO ITEM 309.36 FULL DEPTH RECYCLED PAVEMENT WITH FOAMED ASPHALT.

NOTE:

ALL CALCULATIONS ARE IN CUBIC YARDS

Filename: k:\chapter 2\003_Estimate.dgn Division: HIGHWAY Username: jonathon.french Date:12/19/2007

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-0000(000)X

PIN
PIN 00000.00

HIGHWAY PLANS

SIGNATURE

P.E. NUMBER

DATE

	BY	DATE
PROJ. MANAGER TODD PELLETIER		
DESIGN-DETAILED	S. HASKELL	MAR 2004
CHECKED-REVIEWED	M. MORIN	
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

TOWN
ROUTE

ESTIMATED QUANTITIES AND EARTHWORK SUMMARY

SHEET NUMBER

3

OF 10

Figure 2-4

STATION	CULVERT PIPE RCP SIZE	RCP LENGTH	RCP CLASS	CMP SIZE	CMP LENGTH	OPTION I SIZE	OPTION I LENGTH	OPTION III SMOOTHLINED SIZE	SMOOTHLINED LENGTH	CORRUGATED SIZE	CORRUGATED LENGTH	CATCH BASIN A1-C	B1-C	MH	E	F	PIPE ARCH SPAN	RISE	LENGTH	GAGE OR WALL THICKNESS	UNDERDRAIN TYPE B LENGTH	TYPE C OUTLET LENGTH	SMOOTHLINED SIZE	SMOOTHLINED LENGTH	CORRUGATED SIZE	CORRUGATED LENGTH	ELBOWS, TEES, WYES AND INLET GRATE UNITS DESCRIPTIONS	REMARKS
ROADWAY CULVERTS																												
STA. 25+90 TO 26+15± LT.								12"	28'	15"	28'																	
STA. 26+20								18"	60'	21"	60'																	
STA. 27+50 TO 28+00 LT.								12"	52'	15"	52'																22° ELBOW	
STA. 30+72 RT.								24"	80'	30"	80'																	
STA. 31+40 TO STA. 31+85± LT.								12"	50'	15"	50'																22° ELBOW	UD OUTLET
STA. 31+85								24"	64'																			SMOOTHLINED ONLY
STA. 35+75								18"	66'																			SMOOTHLINED ONLY
STA. 41+25± TO 41+75 LT.								12"	48'																			SMOOTHLINED ONLY
STA. 41+70 TO 41+75 LT.								12"	22'																			SMOOTHLINED ONLY
STA. 46+10 TO STA. 47+25± LT.								15"	116'	18"	116'																	OUTLET PIPE
STA. 46+60 TO STA. 47+73± RT.								12"	114'	15"	114'																	OUTLET PIPE
STA. 48+50± TO STA. 48+70 RT.								12"	24'	15"	24'																30° ELBOW	UD OUTLET
STA. 58+48								18"	58'	21"	58'																	
STA. 63+50								36"	82'	42"	82'																	
STA. 69+23								21"	60'	24"	60'																	
STA. 73+48 LT. & RT.				30"	8'																							EXTEND EXIST. CULV., 2' LT.
STA. 83+25								18"	68'	21"	68'																	SKEWED AHEAD LT., 24°±
STA. 86+75±								30"	70'	36"	70'																	
STA. 86+80± TO STA. 87+20 RT.								15"	44'	18"	44'																30° ELBOW	UD OUTLET
STA. 89+80, 16' RT. - 34' RT.								15"	18'	18"	18'																15 IN. INLET GRATE	INLET PIPE
STA. 105+66								30"	62'	36"	62'																	
STA. 113+30±																												REPLACE EXIST. 18 CULV.
STA. 115+10								21"	62'	24"	62'																	
STA. 123+85 TO STA. 124+00 LT.								12"	22'	15"	22'																45° ELBOW	UD OUTLET
STA. 127+25±	45"	28"	III																									SKEWED AHEAD LT., 45°±
STA. 128+88								30"	56'	36"	56'																	
CATCH BASINS AND MANHOLES																												
STA. 17+06± LT.													1															
STA. 19+80 LT.													1/1/4														9 FT. DEPTH	
STA. 23+80 LT.													1															
STA. 27+50, 28' LT.														1														
STA. 30+58 LT.													1															
STA. 39+30 LT.													1															
STA. 40+50 RT.													1															
STA. 41+25±, 37'± LT.														1														
STA. 41+70 LT.													1															
STA. 41+75±, 38'± LT.																1											TYPE F4-C	
DRIVEWAY CULVERTS																												
STA. 10+10 RT.						15"	36'																					
STA. 12+70 RT.						15"	34'																					
STA. 18+25 RT.						15"	40'																					
STA. 24+55 RT.						15"	38'																					
STA. 26+50 RT.						18"	48'																					
STA. 32+50 LT.						24"	50'																					
STA. 35+40 RT.						15"	38'																					
STA. 76+35 LT.						15"	70'																					
STA. 80+95 RT.						15"	34'																					
STA. 85+12 RT.						15"	32'																					
STA. 94+62 RT.						18"	50'																					
STA. 118+00 RT.						15"	46'																					
STA. 122+15 RT.						15"	42'																					
STA. 127+12 LT.						15"	28'																					
STA. 144+85 RT.						18"	50'																					
STA. 146+65 RT.						15"	44'																					
STA. 151+20 LT.						15"	36'																					
UNDERDRAIN																												
STA. 2+80 TO STA. 7+25 LT.																					445'							
STA. 2+80 TO STA. 7+25 RT.																					445'							
STA. 7+25 TO STA. 7+50 LT.																						28'					22° ELBOW	
STA. 7+25 TO STA. 7+50 RT.																						28'					22° ELBOW	
STA. 12+25± TO STA. 14+60± LT.																					235'							
STA. 14+60± TO STA. 14+90± LT.																						36'					30° ELBOW	
STA. 17+08± TO STA. 19+78 LT.																							12"	270'	15"	270'		
STA. 23+82 TO STA. 25+90 LT.																							12"	208'	15"	208'		
STA. 28+00 TO STA. 30+56 LT.																							12"	256'	15"	256'		
STA. 30+60 TO STA. 31+40 LT.																							12"	80'	15"	80'		
STA. 33+70 TO STA. 35+50 LT.																					180'							
STA. 35+50 TO STA. 35+75± LT.																						34'					45° ELBOW	
STA. 36+40± TO STA. 39+28 LT.																					288'							
STA. 37+55± TO STA. 40+48 RT.																					293'							
STA. 39+32 TO STA. 41+68 LT.																							12"	236'				

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-0000(000)X

PIN 00000.00

HIGHWAY PLANS

SIGNATURE | P.E. NUMBER | DATE

PROJ. MANAGER | DESIGN-DETAILED | CHECKED-REVIEWED | DESIGN2-DETAILED2 | DESIGN3-DETAILED3 | REVISIONS 1 | REVISIONS 2 | REVISIONS 3 | REVISIONS 4 | FIELD CHANGES | BY | DATE

TOWN
ROUTE

DRAINAGE SHEET

SHEET NUMBER
4
OF 10

Filename: k:\chapter 2\004_Drainage.dgn   Division: HIGHWAY   Username: jonathan.french   Date: 12/19/2007

GENERAL NOTES

1. THE UTILITIES INVOLVED IN THIS CONTRACT ARE AS FOLLOWS:

2. ALL UTILITY FACILITIES SHALL BE ADJUSTED BY THE RESPECTIVE UTILITIES UNLESS OTHERWISE NOTED.

3. NO UTILITY INVOLVEMENT IS ANTICIPATED.

4. ALL JOINTS BETWEEN EXISTING AND PROPOSED HOT BITUMINOUS PAVEMENT SHALL BE BUTTED. PAYMENT SHALL BE MADE UNDER ITEM 202.203 PAVEMENT BUTT JOINT.

5. CONSTRUCT BUTT JOINTS AT ALL PAVED DRIVES AND ENTRANCES.

6. GRIND TRANSITION TAPERS AT CATCH BASINS UNDER ITEM NO. 202.203, PAVEMENT BUTT JOINTS, AS DIRECTED BY THE RESIDENT.

7. TRIM ALL TREE BRANCHES TO 20 FEET ABOVE THE PAVEMENT AND 21 FEET FROM CENTERLINE, AS WELL AS ANY BRANCHES DAMAGED BY THE CONTRACTOR DURING CONSTRUCTION. PAYMENT SHALL BE MADE UNDER THE APPROPRIATE RENTAL ITEMS. IF A TREE SPECIALIST IS SUBCONTRACTED FOR THIS WORK, PAYMENT WILL BE MADE BY INVOICE PLUS 5%.

8. CLEARING LIMITS SHALL BE 10' BEYOND AND PARALLEL TO THE CONSTRUCTION SLOPE LINES OR AS SHOWN ON THE PLANS UNLESS OTHERWISE AUTHORIZED BY THE RESIDENT.

9. ALL CLEARING SHALL BE CONSIDERED INCIDENTAL TO THE CONTRACT AND NO SEPARATE PAYMENT WILL BE MADE. THE ACTUAL LINES FOR CLEARING SHALL BE ESTABLISHED IN THE FIELD BY THE CONTRACTOR AND APPROVED BY THE RESIDENT

10. CLEARING LIMITS SHALL BE 15' BEYOND AND PARALLEL TO THE CONSTRUCTION SLOPE LINE IN NON-GUARDRAIL FILL AREAS AND 10' ELSEWHERE. SELECTIVE CLEARING AND THINNING LIMITS SHALL BE BETWEEN THE CLEARING LIMITS AND THE RIGHT OF WAY LINES, OR AS SHOWN ON THE PLANS. (NOTE: INTERSTATE STANDARD)

11. THE CLEARING AND SELECTIVE CLEARING AND THINNING LINES SHOWN ON THE PLANS ARE FOR ESTIMATING PURPOSES ONLY. THE ACTUAL LINES FOR CLEARING AND THINNING SHALL BE ESTABLISHED IN THE FIELD BY THE CONTRACTOR AND APPROVED BY THE RESIDENT.

12. STUMPS HAVE BEEN ESTIMATED TO BE REMOVED UNDER ITEM 201.24, REMOVE STUMP. HOWEVER, WHERE DIRECTED BY THE RESIDENT, ITEM 631.20, STUMP CHIPPER RENTAL, MAY BE USED TO REMOVE STUMPS.

13. GRUBBING IN FILL AREAS HAS BEEN SHOWN ON THE CROSS SECTIONS AND THE QUANTITIES NOTED. THESE LIMITS ARE APPROXIMATE AND HAVE BEEN USED FOR ESTIMATING PURPOSES ONLY. ACTUAL GRUBBING LIMITS MAY VARY BASED ON FIELD CONDITIONS AS DIRECTED BY THE RESIDENT. ESTIMATED GRUBBING DEPTHS ARE ______ INCHES IN FIELD AREAS AND ______ INCHES IN WOODED AREAS.

14. WHERE DEEMED NECESSARY BY THE RESIDENT, UNSUITABLE EXCESS MATERIAL SHALL BE REMOVED FROM THE EDGES OF SHOULDERS AND PLACED IN DESIGNATED AREAS OR DISPOSED OF. PAYMENT WILL BE MADE UNDER THE APPROPRIATE CONTRACT ITEMS.

15. ALL INSLOPE AND DITCHES IN CUT AREAS SHALL BE GRADED AS SHOWN ON THE TYPICALS OR FLATTER, OR AS DIRECTED BY THE RESIDENT.

16. THE CONTRACTOR SHALL PLAN AND CONDUCT THEIR WORK ACCORDINGLY SO THAT UPON FINAL COMPLETION OF THE PROJECT THERE IS NO DROP-OFF FROM THE EDGE OF SHOULDER PAVEMENT. ALL REMAINING OR DISTURBED MATERIAL ON SLOPES OR IN DITCHES ON THE PROJECT SHALL BE CAPABLE OF ATTAINING A GROWTH OF GRASS THAT IS ACCEPTABLE ACCORDING TO STANDARD SPECIFICATION 618.10. NO SEPARATE PAYMENT WILL BE MADE FOR THIS WORK.

17. DRIVEWAY FILL SIDE SLOPES SHALL BE THE SAME AS THE NON-GUARDRAIL FILL SLOPES UNLESS OTHERWISE NOTED ON THE PLANS.

18. ALL WASTE MATERIAL NOT USED ON THE PROJECT SHALL BE DISPOSED OF OFF THE PROJECT IN WASTE AREAS APPROVED BY THE RESIDENT.

19. REQUIRED DITCH PROTECTION SHOWN ON THE PLANS OR IN THE CONSTRUCTION NOTES IS FOR ESTIMATING PURPOSES ONLY. THE ACTUAL TYPE AND LOCATION OF DITCH PROTECTION MAY BE ALTERED BY THE RESIDENT.

20. IF FOUNDATION MATERIAL IS REQUIRED UNDER CULVERTS, IT SHALL MEET THE REQUIREMENTS FOR GRANULAR BORROW - UNDERWATER BACKFILL AND WILL PAID FOR AS GRANULAR BORROW.

21. GRANULAR BORROW USED TO BACKFILL MUCK EXCAVATION OR IN LOW WET AREAS TO 1' ABOVE WATER LEVEL OR OLD GROUND SHALL MEET REQUIREMENTS FOR GRANULAR BORROW UNDERWATER BACKFILL.

22. EXISTING INSLOPES STEEPER THAN 2:1 IN PROPOSED FILL AREAS SHALL BE BENCHED AS DIRECTED BY THE RESIDENT.

25. RESIDENTIAL PAVED ENTRANCES SHALL BE CONSTRUCTED WITH: 2" HOT MIX ASPHALT AND 12" AGGREGATE SUBBASE COURSE GRAVEL.

26. COMMERICAL PAVED ENTRANCES SHALL BE CONSTRUCTED WITH: 3" HOT MIX ASPHALT AND 11" AGGREGATE SUBBASE COURSE GRAVEL.

27. UNPAVED ENTRANCES SHALL BE CONSTRUCTED WITH 14" AGGREGATE SUBBASE COURSE GRAVEL OR 11" AGGREGATE SUBBASE COURSE GRAVEL AND 3" UNTREATED AGGREGATE SURFACE COURSE UNLESS OTHERWISE NOTED IN THE PLANS OR DIRECTED BY THE RESIDENT

28. CRUSHED STONE ENTRANCES SHALL BE CONSTRUCTED WITH 12" AGGREGATE SUBBASE COURSE GRAVEL AND 2" CRUSHED STONE SURFACE UNLESS OTHERWISE NOTED IN THE PLANS OR DIRECTED BY THE RESIDENT

29. GRASSED ENTRANCES SHALL BE CONSTRUCTED WITH 12" AGGREGATE SUBBASE COURSE GRAVEL AND 2" LOAM, SEED & MULCH UNLESS OTHERWISE NOTED IN THE PLANS OR DIRECTED BY THE RESIDENT

30. A 3' PAVED LIP SHALL BE PLACED AT ALL GRAVEL ENTRANCES UNLESS OTHERWISE NOTED IN THE PLANS OR DIRECTED BY THE RESIDENT.

31. ALL PAVED WALKS TO BE CONSTRUCTED WITH 12" AGGREGATE SUBBASE COURSE-GRAVEL AND 2" HOT MIX ASPHALT UNLESS OTHERWISE NOTED IN THE PLANS OR DIRECTED BY THE RESIDENT

32. PLACE 12 INCHES GRAVEL AND 2 INCHES HOT MIX ASPHALT AROUND CATCH BASINS IN GRASSED AREAS (3' OUTSIDE OF FRAME) AND PAINT WITH ACRYLIC LATEX COLOR FINISH - GREEN. PAYMENT SHALL BE UNDER THE APPLICABLE CONTRACT ITEMS.

33. ITEM # 411.10, UNTREATED AGGREGATE SURFACE COURSE, MAY ALSO MEET THE GRADATION REQUIREMENTS OF ITEM # 204.20. ADD SHOULDER AGGREGATE.

34. ANY NECESSARY CLEANING OF EXISTING PAVEMENT PRIOR TO PAVING SHALL BE INCIDENTAL TO THE RELATED PAVING ITEMS.

35. ALL EXISTING PAVED SHOULDERS AND WIDENINGS TO BE RESURFACED AS DIRECTED BY THE RESIDENT.

36. SHOULDER SHIM SHALL TAPER TO 0 MM [0 IN] PRIOR TO FACE OF EXISTING CURB AND GUARDRAIL.*

37. WHEN SUPER ELEVATION EXCEEDS THE SLOPE OF THE LOW SIDE SHOULDER, THE SHOULDER PAVEMENT WILL HAVE SAME SLOPE AS TRAVELED WAY.

38. THE FOLLOWING SHALL BE INCIDENTAL TO THE 603 ITEM(S):
   - ANY CUTTING OF EXISTING CULVERTS AND OR CONNECTORS NECESSARY TO INSTALL NEW CULVERT REPLACEMENTS OR EXTENSIONS
   - ALL PIPE EXCAVATION INCLUDING ANY CUTTING AND REMOVAL OF PAVEMENT
   - ALL DITCHING AT PIPE ENDS
   - FURNISHING, PLACING, GRADING, AND COMPACTING OF ANY NEW GRAVEL AND/OR FILL MATERIAL INCLUDING GRANULAR BORROW USED UNDER PIPES AND FOR TEMPORARY DETOURS TO MAINTAIN TRAFFIC DURING PIPE INSTALLATION (EXCAVATION IS ALSO INCIDENTAL).
   - GRANULAR BORROW UNDER THE PIPE SHALL MEET THE REQUIREMENTS FOR UNDERWATER BACKFILL
   - ALL WORK NECESSARY TO CONNECT TO EXISTING PIPES AND DRAINAGE STRUCTURES
   - FLOW LINES MAY BE CHANGED BY 1.5 FT
   - ANY NECESSARY CLEARING OF BRUSH AND NON-PAY TREES AT CULVERT ENDS

39. EXISTING CULVERTS TO REMAIN SHALL BE CLEANED AS DIRECTED BY THE RESIDENT. PAYMENT WILL BE MADE UNDER ITEM 631.32 CULVERT CLEANER (INCLUDING OPERATOR).

40. EXISTING CULVERTS AND CATCH BASINS WILL BE CLEANED AS DIRECTED BY THE RESIDENT UNDER THE APPROPRIATE PAY ITEMS.

41. NO EXISTING DRAINAGE SHALL BE ABANDONED, REMOVED OR PLUGGED WITHOUT PRIOR APPROVAL OF THE RESIDENT.

42. INLETS AND OUTLETS OF ALL CULVERTS SHALL BE RIPRAPPED UNLESS OTHERWISE NOTED ON THE PLANS OR DIRECTED BY THE RESIDENT.

43. THE CULVERT SIZES SHOWN ON THE PLANS AND CROSS SECTIONS ARE FOR SMOOTHLINED PIPES. FOR COMPARABLE CORRUGATED SIZES SEE THE DRAINAGE TABULATION.

44. ANY NECESSARY CUTTING OF EXISTING PIPES TO FIT IN AREAS OF PROPOSED CATCH BASINS WILL NOT BE PAID FOR SEPARATELY AND WILL BE CONSIDERED INCIDENTAL TO ITEM 604.

45. ANY NECESSARY CUTTING OF EXISTING CATCH BASINS TO ALLOW FOR PROPOSED PIPE CONNECTIONS WILL NOT BE PAID FOR SEPARATELY AND WILL BE CONSIDERED INCIDENTAL TO ITEM 603 OR 605.

46. AS DIRECTED BY THE RESIDENT, ALL EXISTING UNDERDRAIN OUTLETS SHALL BE LOCATED, CLEANED OUT AND DITCHED AS REQUIRED OR REPLACED AS NECESSARY. PAYMENT WILL BE MADE UNDER APPROPRIATE CONTRACT ITEMS.

47. ALL CONNECTIONS FOR UNDERDRAIN (U.D.) TO ROADWAY CULVERTS WILL BE INCIDENTAL TO U.D. PIPE ITEMS.

48. A 3 FT. X 3 FT. SQUARE RIPRAP PAD SHALL BE CONSTRUCTED AT U.D. OUTLETS.

49. EXISTING ABANDONED WATER MAINS BROKEN BY THE CONTRACTOR DURING CONSTRUCTION SHALL HAVE THE ENDS PLUGGED WITH BRICK AND MORTAR. COST FOR ALL LABOR AND MATERIAL WILL BE CONSIDERED INCIDENTAL TO THE CONTRACT AND NO DIRECT PAYMENT WILL BE MADE.

50. GUARDRAIL END TREATMENTS SHALL BE INSTALLED CONCURRENTLY WITH THE PLACEMENT OF EACH SECTION OF BEAM GUARDRAIL.

51. GUARDRAIL WHICH IS REMOVED AND NOT REUSED ON THE PROJECT BECOMES PROPERTY OF THE STATE AND SHALL BE DELIVERED TO ______ REMOVAL, DELIVERY, DISMANTLING, AND STACKING SHALL BE INCIDENTAL TO THE GUARDRAIL ITEMS.

52. HOLES CREATED BY GUARDRAIL REMOVAL WILL BE FILLED AND COMPACTED WITH APPROVED MATERIALS AS DIRECTED BY THE RESIDENT. PAYMENT TO BE CONSIDERED INCIDENTAL TO THE GUARDRAIL ITEMS.

53. ALL EXISTING GUARDRAIL SHALL BE REMOVED AND BECOME THE PROPERTY OF THE CONTRACTOR. REMOVAL AND DISPOSAL SHALL BE CONSIDERED INCIDENTAL TO THE GUARDRAIL ITEMS.

54. TWO REFLECTORIZED FLEXIBLE G.R. MARKERS (ITEM 606.353) WILL BE INSTALLED AT EACH GUARDRAIL END. A DELINEATOR POST (ITEM 606.35) WILL BE INSTALLED AT EACH UNDERDRAIN OUTLET.

55. CONNECTIONS FOR PROPOSED GUARDRAIL TO EXISTING GUARDRAIL WILL BE CONSIDERED INCIDENTAL TO ITEM 606.

56. ALL CATCH BASINS TYPE A PLACED ON CIRCULAR CURB TYPE I SHALL HAVE THE CURB INLET CUT THE SAME RADIUS AS ADJACENT CIRCULAR CURB. PAYMENT SHALL BE INCIDENTAL TO ITEM 604

57. IN AREAS WHERE CURB TYPE I WILL BE RESET, THE EXISTING CURB SUITABLE FOR USE AS TERMINAL ENDS SHALL BE CUT IF NECESSARY AND UTILIZED AS SUCH AND PAID FOR UNDER ITEM 609.38 (RESET CURB TYPE 1).

58. BACKING UP BITUMINOUS CURB IS INCIDENTAL TO THE CURB ITEMS. IN AREAS WHERE NEW BITUMINOUS CURB IS DESIGNATED TO REPLACE EXISTING, THE REMOVAL OF THE OLD BITUMINOUS CURB SHALL BE INCIDENTAL TO THE NEW CURB.

59. LOAM HAS BEEN ESTIMATED FOR DISTURBED LAWN AREAS.. ACTUAL PLACEMENT OF THE LOAM SHALL BE AS NOTED ON THE PLANS OR DESIGNATED BY THE RESIDENT.

62. LOAM SHALL BE PLACED TO A NOMINAL DEPTH OF 4 INCHES IN LAWN AREAS AND 2 INCHES IN ALL OTHER AREAS UNLESS OTHERWISE NOTED OR DIRECTED.

63. DIRTY BORROW SHALL BE PLACED TO A NOMINAL DEPTH OF 2 INCHES UNLESS OTHERWISE NOTED OR DIRECTED.

64. ACRYLIC LATEX COLOR FINISH GREEN (ITEM 658.20) SHALL BE PLACED ON ALL PAVED ISLANDS.

65. WHITE PAVEMENT/CURB MARKING (ITEM 627.65) SHALL BE APPLIED TO ALL ISLAND TAPERED ENDS.

68. ANY DAMAGE TO THE SLOPES CAUSED BY THE CONTRACTOR'S EQUIPMENT, PERSONNEL, OR OPERATION SHALL BE REPAIRED TO THE SATISFACTION OF THE RESIDENT. ALL WORK, EQUIPMENT, AND MATERIALS REQUIRED TO MAKE REPAIRS SHALL BE AT THE CONTRACTOR'S EXPENSE.

70. NO SEPARATE PAYMENT FOR SUPERINTENDENT OR FOREMAN WILL BE MADE FOR THE SUPERVISION OF EQUIPMENT BEING PAID FOR UNDER THE EQUIPMENT RENTAL ITEMS.

GEOTECHNICAL NOTES

1. BIDDERS AND CONTRACTORS MAY OBTAIN A COPY OF THE PROJECT GEOTECHNICAL REPORT MAINEDOT SOILS REPORT NUMBER 2007-XX, DATED DECEMBER 2007, BY CONTACTING THE PROJECT MANAGER.

2. GEOTECHNICAL INFORMATION FURNISHED OR REFERRED TO IN THIS PLAN SET IS FOR THE BIDDER'S AND CONTRACTOR'S USE. NO ASSURANCE IS GIVEN THAT THE INFORMATION OR INTERPRETATIONS WILL BE REPRESENTATIVE OF ACTUAL SUBSURFACE CONDITIONS AT THE TIME OF CONSTRUCTION. THE DEPARTMENT SHALL NOT BE RESPONSIBLE FOR THE BIDDER'S AND CONTRACTOR'S INTERPRETATIONS OF, OR CONCLUSIONS DRAWN FROM, THE GEOTECHNICAL INFORMATION. THE BORING LOGS CONTAINED IN THE PLAN SET PRESENT FACTUAL AND INTERPRETIVE SUBSURFACE INFORMATION COLLECTED AT DISCRETE LOCATIONS. DATA PROVIDED MAY NOT BE REPRESENTATIVE OF THE SUBSURFACE CONDITIONS BETWEEN BORING LOCATIONS.

3. EXISTING PAVEMENT SHALL NOT BE USED AS COLD-IN-PLACE RECLAIM SUBBASE AGGREGATE. THE CONTRACTOR MAY USE SALVAGED PAVEMENT MATERIALS FOR TRAFFIC MAINTENANCE AND THEN STABILIZE IT IN ACCORDANCE WITH SPECIAL PROVISION 308.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-0000(000)X

PIN 00000.00

HIGHWAY PLANS

PROJ. MANAGER
DESIGN-DETAILED
CHECKED-REVIEWED
DESIGN2-DETAILED2
DESIGN3-DETAILED3
REVISIONS 1
REVISIONS 2
REVISIONS 3
REVISIONS 4
FIELD CHANGES

BY | DATE

SIGNATURE
P.E. NUMBER
DATE

TOWN
ROUTE

GENERAL NOTES

SHEET NUMBER

5

OF 10

Filename: ...\005_GENERAL_Notes.dgn   Division: HIGHWAY   Username: jonathon.french   Date:12/19/2007

DRIVEWAYS & ENTRANCES & ISLANDS & YARDS

LOCATION			DESCRIPTION	OPENING
48+41		LT	PAVED ENTRANCE	
48+60	TO 49+96	LT	PAVED ISLAND AND YARD	
50+05		RT	PAVED DRIVE	44 FT.
50+11		LT	PAVED ENTRANCE	30 FT.
50+26	TO 50+92	LT	PAVED ISLAND AND YARD	
51+25		LT	PAVED ENTRANCE	
51+55	TO 53+00	LT	PAVED ISLAND AND YARD	
52+37		RT	PAVED DRIVE	32 FT.
53+13		LT	PAVED ENTRANCE	
53+45		LT	PAVED ENTRANCE	
53+97		RT	PAVED ENTRANCE	42 FT.
54+18	TO 54+31	RT	PAVED ISLAND AND YARD	
54+50		LT	PAVED ENTRANCE	
54+51.5		RT	PAVED ENTRANCE	41 FT.
54+72	TO 55+08	RT	PAVED ISLAND AND YARD	
55+15		LT	PAVED ENTRANCE	42 FT.
55+23		RT	PAVED ENTRANCE	30 FT.
55+38	TO 55+80	RT	PAVED ISLAND AND YARD	
56+01		RT	PAVED ENTRANCE	42 FT.
56+22	TO 56+48	RT	PAVED ISLAND AND YARD	
56+56		LT	PAVED ENTRANCE	42 FT.
57+08		RT	PAVED ENTRANCE	32 FT.
58+21		RT	PAVED ENTRANCE	32 FT.
58+40		LT	PAVED DRIVE	20 FT.
61+92		LT	PAVED ENTRANCE	
62+38		LT	PAVED ENTRANCE	
62+58	TO 63+69	LT	PAVED ISLAND AND YARD	
63+90		LT	PAVED ENTRANCE	42 FT.
63+92		RT	PAVED ENTRANCE	
64+11	TO 64+37	LT	PAVED ISLAND AND YARD	
65+36		LT	PAVED ENTRANCE	
67+12		LT	PAVED DRIVE	
67+45	SKEWED AHEAD	RT	PAVED DRIVE	28 FT.
69+71		RT	PAVED DRIVE	26 FT.
70+41		RT	PAVED DRIVE	30 FT.
70+69	SKEWED BACK	LT	PAVED DRIVE	32 FT.
71+07		RT	PAVED DRIVE	26 FT.
71+73		LT	PAVED ENTRANCE	42 FT.
72+97		RT	PAVED ENTRANCE	26 FT.
75+47		RT	PAVED ENTRANCE	24 FT.
76+30	TO 77+21	LT	PAVED ENTRANCE	
76+87		RT	PAVED DRIVE	22 FT.
77+72		RT	PAVED DRIVE	24 FT.
78+41		RT	PAVED DRIVE	
78+73		RT	PAVED DRIVE	
78+87		LT	PAVED DRIVE	24 FT.
80+04		RT	PAVED DRIVE	42 FT.
80+68		RT	PAVED ENTRANCE	20 FT.
80+87		LT	PAVED DRIVE	32 FT.
82+75		RT	PAVED DRIVE	32 FT.
82+78		LT	PAVED ENTRANCE	42 FT.
83+18		RT	PAVED CURB OPENING	20 FT.
83+90		RT	PAVED DRIVE	20 FT.
84+08		LT	PAVED DRIVE	24 FT.
84+57		LT	PAVED ENTRANCE	42 FT.
84+72	TO 84+89	LT	PAVED ISLAND AND YARD	
85+02		RT	PAVED DRIVE	24 FT.
85+11		LT	PAVED ENTRANCE	
85+59		RT	PAVED DRIVE	24 FT.
87+40		RT	PAVED ENTRANCE	60 FT.
87+51		LT	PAVED DRIVE	34 FT.
88+10		LT	PAVED ENTRANCE	28 FT.
89+45		LT	PAVED ENTRANCE	42 FT.
90+13	SKEWED AHEAD	RT	PAVED ENTRANCE	32 FT.
91+18		LT	PAVED ENTRANCE	
51+19.82	TO 51+29.82	LT	PAVED ISLAND	
53+21	TO 53+33	LT	PAVED ISLAND	
62+09.60	TO 62+17.10	LT	PAVED ISLAND	

WALK WAYS

LOCATION		DESCRIPTION
58+01	LT	PAVED WALK
69+36	LT	PAVED WALK
72+65	RT	PAVED WALK
77+21	RT	PAVED WALK
80+43	LT	PAVED WALK
82+98	RT	PAVED WALK
83+66	RT	PAVED WALK

CLEARING - ITEM # 201.11

STATION	TO	STATION	
50+30	TO	52+09	RT.
58+67	TO	62+15	RT.
58+93	TO	61+74	LT.
64+49	TO	67+49	RT.
66+20	TO	66+95	LT.
67+87	TO	69+35	RT.
68+97	TO	69+23	LT.
71+13	TO	71+50	LT.
71+32	TO	72+24	RT.
74+18	TO	74+99	LT.
74+71	TO	74+93	RT.

REMOVING SINGLE TREE TOP ONLY - ITEM # 201.23

STATION	OFFSET		DESCRIPTION	QUANTITY	
53+43.20	35.7′	RT.	18″ OAK	1	EACH
67+27.50	25.3′	LT.	34″ OAK	1	EACH
71+28.70	25.3′	LT.	32″ WHITE OAK	1	EACH
86+20	28.3′	LT.	26″ MAPLE	1	EACH
86+58.60	31.6′	LT.	12″ MAPLE	1	EACH
86+61	28.8′	LT.	12″ MAPLE	1	EACH

REMOVING STUMPS - ITEM # 201.24

STATION	OFFSET		DESCRIPTION	QUANTITY	
53+43.20	35.7′	RT.	18″ OAK	1	EACH
67+27.50	25.3′	LT.	34″ OAK	1	EACH
71+28.70	25.3′	LT.	32″ WHITE OAK	1	EACH
86+20	28.3′	LT.	26″ MAPLE	1	EACH
86+58.60	31.6′	LT.	12″ MAPLE	1	EACH
86+61	28.8′	LT.	12″ MAPLE	1	EACH

ALTER CATCH BASIN TO MANHOLE - ITEM # 604.16

STATION	OFFSET		QUANTITY	
72+89.20	33.90′	LT.	1	EACH

ADJUST MANHOLE OR CATCH BASIN TO GRADE - ITEM # 604.18

STATION	OFFSET		QUANTITY	
54+93.70	27.50′	RT.	1	EACH
72+88.10	30.90′	RT.	1	EACH

GUARD RAIL TYPE 3c - SINGLE RAIL - ITEM # 606.23

STATION TO STATION	LENGTH
59+50 - 63+00 RT.	350 LF*
58+96 - 61+45 LT.	250 LF**
65+07 - 67+07 RT.	200 LF
65+60 - 65+85 LT.	25 LF

* CONNECT GUARDRAIL END AT 59+50 TO THE LEDGE OR BURY IN THE BACKSLOPE AS PER SPECIAL GUARD RAIL DETAIL SHEET OR AS DIRECTED BY THE RESIDENT.

** CONNECT GUARD END AT 58+96 TO THE LEDGE OR BURY IN THE BACKSLOPE AS PER SPECIAL GUARD RAIL DETAIL SHEET OR AS DIRECTED BY THE RESIDENT.

GUARD RAIL 350 FLARED TERMINAL - ITEM # 606.79

STATION TO STATION	QUANTITY
63+00 - 63+37.5 RT.	1 EA
67+07 - 67+44.5 RT.	1 EA

CURB TYPE 3 MOLD 2 - ITEM # 609.31

STATION TO STATION	LENGTH
80+79 - 82+64 RT.	185 LF
82+86 - 83+07 RT.	21 LF
83+29 - 83+88 RT.	59 LF

CURB TYPE 3 MOLD 3 - ITEM # 609.31

STATION TO STATION	LENGTH
85+13 - 85+48 RT.	35 LF

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-0000(000)X

PIN
00000.00

HIGHWAY PLANS

		BY	DATE
PROJ. MANAGER	ERNIE MARTIN		
DESIGN-DETAILED	B.C.	M.P.	APR 2005
CHECKED-REVIEWED			
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

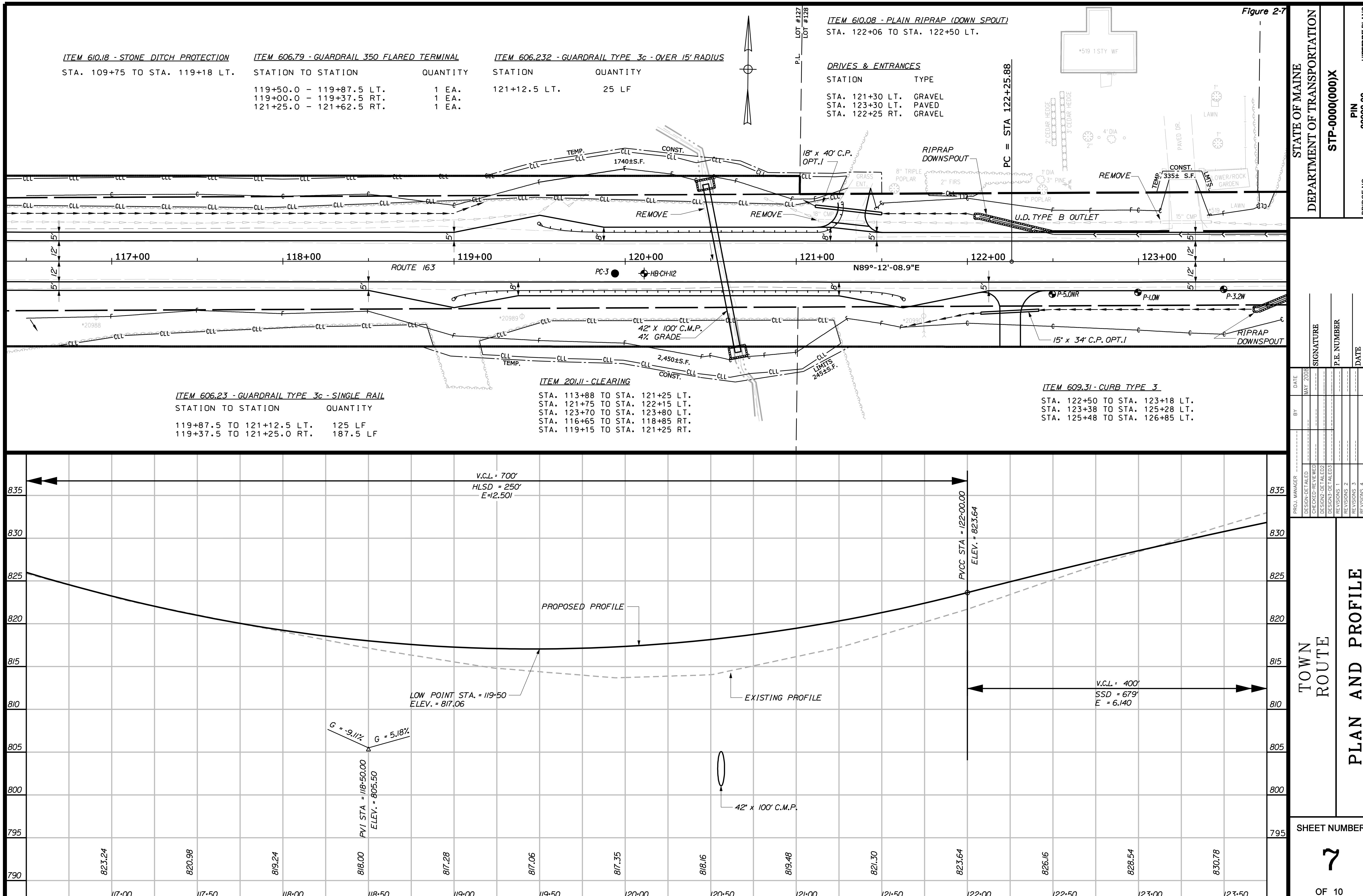
P.E. NUMBER

DATE

TOWN
ROUTE

CONSTRUCTION NOTES

Filename: k:\chapter 2\007_PLAN_PROF.DGN Division: HIGHWAY Username: jonathon.french Date:12/19/2007



CURVE DATA
DAB REPORT FOR STRING MR02 = NEW & EXIST. CURB LT. ON RAMP NO. 3
EXIST. INSTALLED BY OTHERS UNDER PROJECT NO. IM-295-1098(810)E

PBC 1 0+00.00 1000831.67 291150.39
PI = 0+47.24
D = 71° - 37′ - 11.1″
I = 61° - 07′ - 29.0″ LT
R = 80.00
L = 85.35
T = 47.24
E = 12.91
LC = S 70 ° - 45′ - 14.8″ E 81.36′
PI COORD.= 1000862.16 291114.30
CP COORD.= 1000892.78 291202.02
PT 93 0+85.35 1000908.48 291123.57
N 78° - 41′ - 00.7″ E 260.12′
ANG. PT. 357 3+45.47 1001163.54 291174.61
AND PCC
PI = 4+29.28
D = 02° - 00′ - 55.7″
I = 03° - 22′ - 37.1″ LT
R = 2842.79
L = 167.55
T = 83.80
E = 1.23
LC = N 73° - 38′ - 51.2″ E 167.53′
PI COORD.= 1001244.62 291195.83
CP COORD.= 1000443.90 293924.81
PAC 528 5+13.03 1001324.30 291221.78

CURVE DATA
DAB REPORT FOR STRING MR03 = PROP. ISLAND ON RAMP NO. 3

PBT 1 0+00.00 1000862.585 291070.879
S 73° - 38′ - 33.7″ E 1.70′
PC 5 0+01.70 1000860.954 291070.401
RAD = 4.00′ RT.
L = 5.71′
PT 17 0+17.41 1000856.189 291072.576
N 24° - 34′ - 03.3″ W 14.81′
PC 48 0+22.22 1000850.030 291086.049
RAD = 2.00′ RT.
L = 4.59′
PRC 58 0+26.81 1000852.431 291088.794
RAD = 141.00′ LT.
L = 5.23′
PT 71 0+32.04 1000857.499 291087.330
S 17° - 13′ - 06.2″ E 17.27′
PAT 106 0+49.31 1000862.585 291070.879

CURVE DATA
DAB REPORT FOR STRING MR04 = PROP. ISLAND ON RAMP NO. 3

PBT 1 0+00.00 1000870.908 291073.323
N 73° - 36′ - 46.7″ E 19.47′
PC 40 0+19.47 1000889.583 291078.815
RAD = 2.00′ LT.
L = 5.65′
PRC 53 0+25.12 1000889.080 291082.733
RAD = 141.00′ RT.
L = 21.89′
PT 99 0+47.01 1000867.285 291085.030
S 17° - 11′ - 52.6″ E 12.33′
PAT 124 0+59.34 1000870.908 291073.323

GEOMETRICS
STATION & OFFSETS FOR MR03 TO MC10

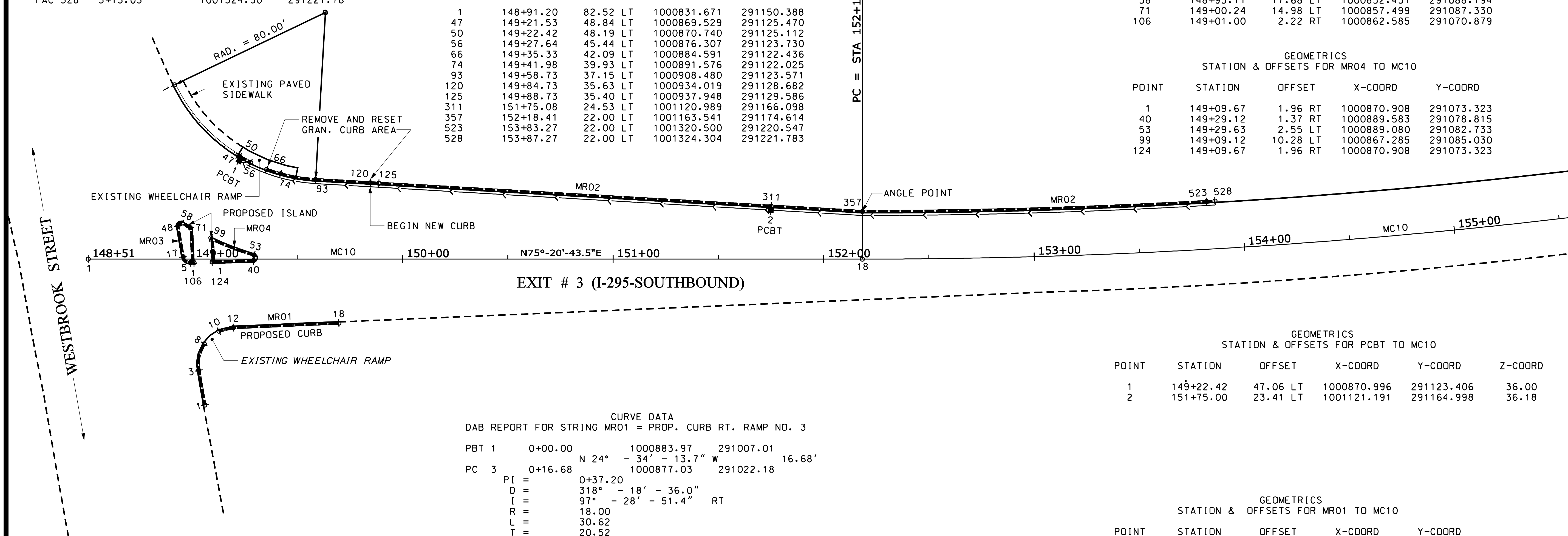
POINT	STATION	OFFSET	X-COORD	Y-COORD
1	149+01.00	2.22 RT	1000862.585	291070.879
5	148+99.30	2.27 RT	1000860.954	291070.401
17	148+95.24	1.04 LT	1000856.189	291072.576
48	148+92.69	15.63 LT	1000850.030	291086.049
58	148+95.71	17.68 LT	1000852.431	291088.794
71	149+00.24	14.98 LT	1000857.499	291087.330
106	149+01.00	2.22 RT	1000862.585	291070.879

GEOMETRICS
STATION & OFFSETS FOR MR02 TO MC10

POINT	STATION	OFFSET	X-COORD	Y-COORD
1	148+91.20	82.52 LT	1000831.671	291150.388
47	149+21.53	48.84 LT	1000869.529	291125.470
50	149+22.42	48.19 LT	1000870.740	291125.112
56	149+27.64	45.44 LT	1000876.307	291123.730
66	149+35.33	42.09 LT	1000884.591	291122.436
74	149+41.98	39.93 LT	1000891.576	291122.025
93	149+58.73	37.15 LT	1000908.480	291123.571
120	149+84.73	35.63 LT	1000934.019	291128.682
125	149+88.73	35.40 LT	1000937.948	291129.586
311	151+75.08	24.53 LT	1001120.989	291166.098
357	152+18.41	22.00 LT	1001163.541	291174.614
523	153+83.27	22.00 LT	1001320.500	291220.547
528	153+87.27	22.00 LT	1001324.304	291221.783

GEOMETRICS
STATION & OFFSETS FOR MR04 TO MC10

POINT	STATION	OFFSET	X-COORD	Y-COORD
1	149+09.67	1.96 RT	1000870.908	291073.323
40	149+29.12	1.37 RT	1000889.583	291078.815
53	149+29.63	2.55 LT	1000889.080	291082.733
99	149+09.12	10.28 LT	1000867.285	291085.030
124	149+09.67	1.96 RT	1000870.908	291073.323



GEOMETRICS
STATION & OFFSETS FOR PCBT TO MC10

POINT	STATION	OFFSET	X-COORD	Y-COORD	Z-COORD
1	149+22.42	47.06 LT	1000870.996	291123.406	36.00
2	151+75.00	23.41 LT	1001121.191	291164.998	36.18

CURVE DATA
DAB REPORT FOR STRING MR01 = PROP. CURB RT. RAMP NO. 3

PBT 1 0+00.00 1000883.97 291007.01
N 24° - 34′ - 13.7″ W 16.68′
PC 3 0+16.68 1000877.03 291022.18
PI = 0+37.20
D = 318° - 18′ - 36.0″
I = 97° - 28′ - 51.4″ RT
R = 18.00
L = 30.62
T = 20.52
E = 9.29
LC = N 24° - 10′ - 12.0″ E 27.06′
PI COORD.= 1000868.50 291040.84
CP COORD.= 1000893.40 291029.66
PT 12 0+47.30 1000888.11 291046.86
N 72° - 54′ - 37.7″ E 50.20′
PAT 18 0+97.51 1000936.10 291061.62

GEOMETRICS
STATION & OFFSETS FOR MR01 TO MC10

POINT	STATION	OFFSET	X-COORD	Y-COORD
1	149+05.53	69.43 RT	1000883.969	291007.006
3	149+02.65	53.00 RT	1000877.033	291022.175
8	149+05.36	39.98 RT	1000876.362	291035.456
10	149+12.58	33.67 RT	1000881.752	291043.380
12	149+19.62	31.91 RT	1000888.114	291046.865
18	149+69.78	29.78 RT	1000936.101	291061.618

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
STP-0000(000)X
PIN 00000.00
HIGHWAY PLANS

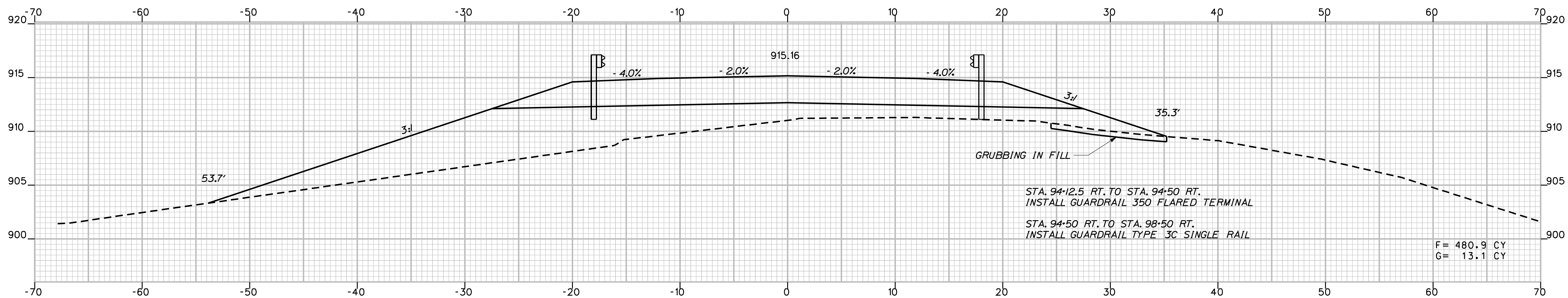
	BY	DATE
PROJ. MANAGER	E.M.	
DESIGN-DETAILED	M. MOREAU	JUNE 2007
CHECKED-REVIEWED	T. WHITE	
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE
P.E. NUMBER
DATE

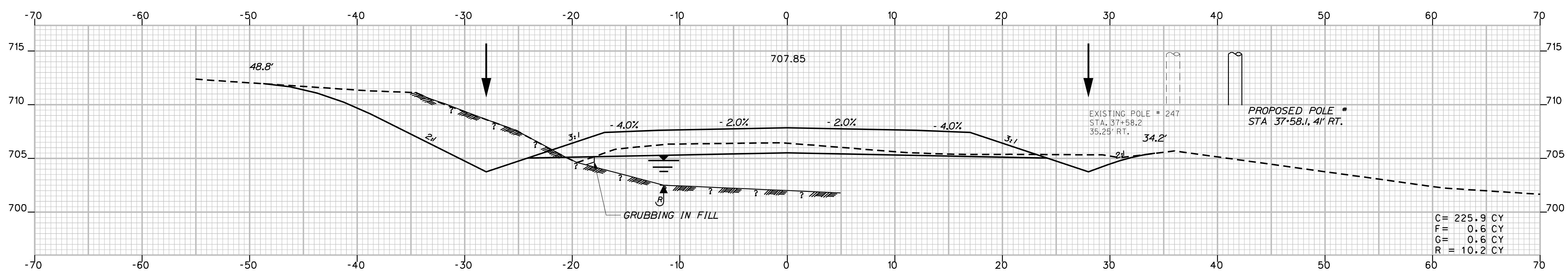
TOWN
PROJECT
GEOMETRICS AND CURB LAYOUT

SHEET NUMBER
8
OF 10

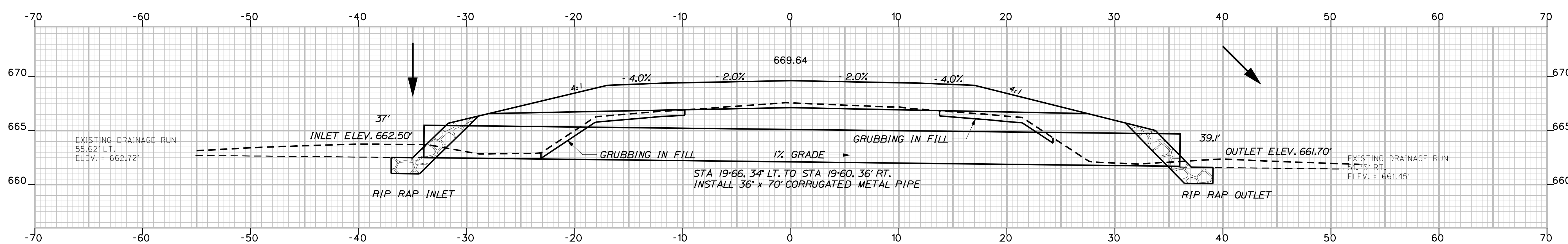
Figure 2-9



94+50.00



37+50.00



19+70.00

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-0000(000)X

PIN 00000.00

HIGHWAY PLANS

		BY	DATE
PROJ. MANAGER	M.M.		
DESIGN-DETAILED	J.K.	M.R.P.	
CHECKED-REVIEWED		M.B.	
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE
P.E. NUMBER
DATE

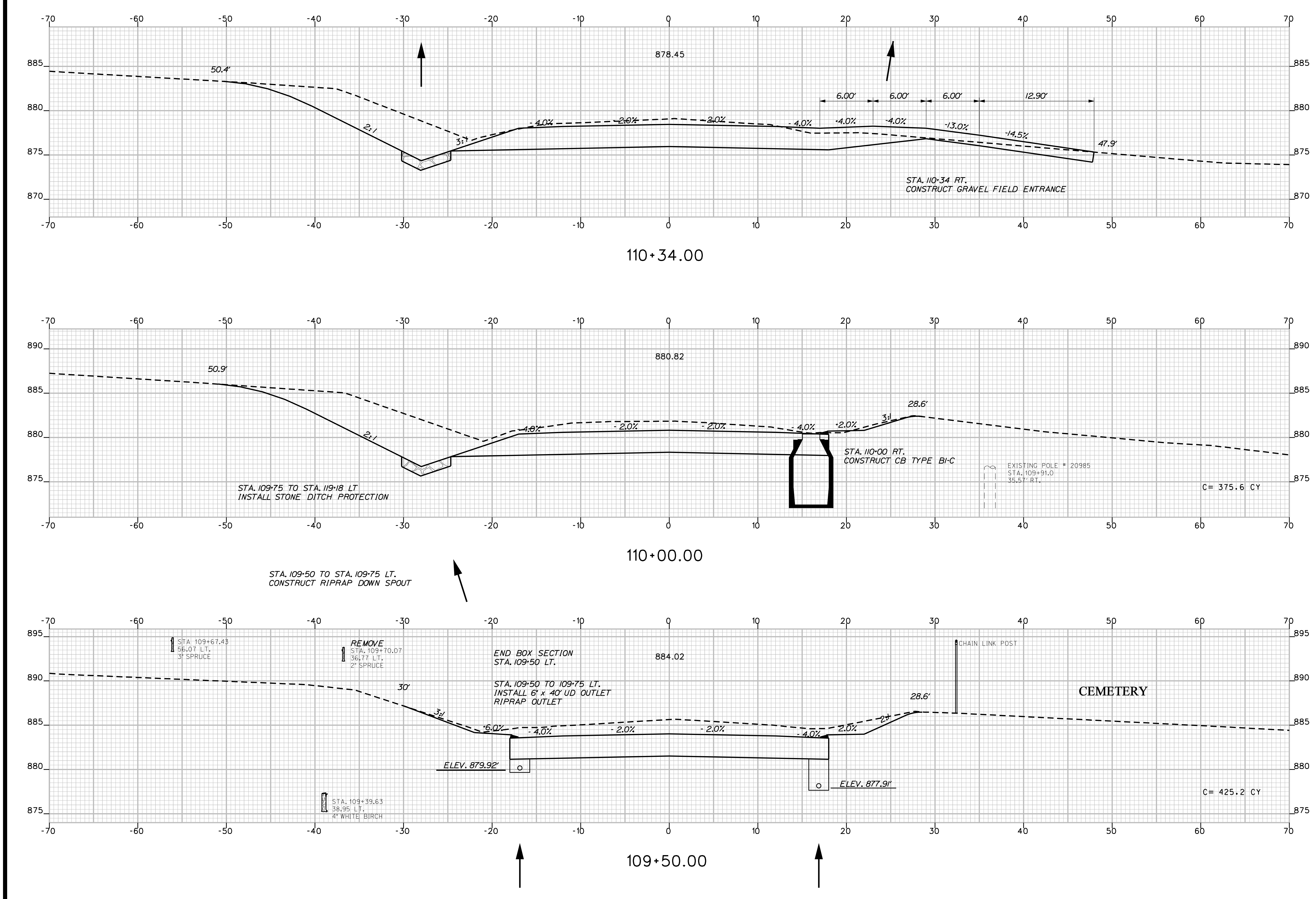
TOWN
ROUTE

CROSS SECTIONS 00+00.00 00+00.00

SHEET NUMBER
9
OF 10

Filename: ...\009_cross section_001.dgn
Division: HIGHWAY
Username: jonathon.french
Date:12/19/2007

Figure 2-10



STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-0000(000)X

PIN
00000.00

HIGHWAY PLANS

	J.K.	BY	DATE
PROJ. MANAGER			
DESIGN-DETAILED	M.M.	M.R.P.	
CHECKED-REVIEWED			
DESIGN2-DETAILED2		M.B.	
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

DATE

TOWN
ROUTE

CROSS SECTIONS 000+00.00
000+00.00

SHEET NUMBER
10
OF 10

Filename: ...\010_cross section_002.dgn Division: HIGHWAY Username: jonathon.french Date:12/19/2007

CHAPTER THREE

BASIC DESIGN CONTROLS

Volume I

- Highway Design Guide –

National Standards

December 2004

Chapter Three

TABLE OF CONTENTS

Page

Chapter Three
BASIC DESIGN CONTROLS

3-1 *HIGHWAY DESIGN GUIDE* APPLICATION

3-1.01 General

1. ***Project Types***. The *Guide* applies to all projects on State highways or the Federal-aid system regardless of the source of funding. The *Guide* also applies to all projects off the State highway or Federal-aid system when Federal-aid participation or State funding is involved.

2. ***Preparation of Plans***. The *Guide* will be used by the Maine Department of Transportation, consultants retained by the Department, local governments and private developers for the preparation of plans for all projects to which the *Guide* applies.

3-1.02 Definitions

Many qualifying words are used in highway design and in this *Guide*. For consistency and uniformity in the application of various design criteria, the following definitions apply:

1. ***Shall, require, will, must***. A mandatory condition. Designers are obligated to adhere to the criteria and applications presented in this context. Generally, these statements are not included in this *Guide* for the application of geometric design and roadside safety criteria.

2. ***Should, recommend***. An advisory condition. Designers are encouraged to follow the criteria and guidance presented in this context, unless there is justification not to do so.

3. ***May, could, can, suggest, consider***. A permissive condition. Designers are allowed to apply individual judgment and discretion to the criteria when presented in this context. The decision will be based on a case-by-case assessment.

4. ***Desirable, preferred***. An indication that the designer should make an effort to meet the criteria

5. ***Minimum, maximum, upper, lower***. Representative of the limits of acceptability, although not implying that they are inviolable. Where the criteria presented in this context will not be met, the designer will in many cases need to request approval.

6. ***Practical, feasible, cost-effective, reasonable***. The designer will apply the design criteria based on a subjective analysis of the relative benefits and costs associated with the impacts of the decision. No formal analysis is intended, unless otherwise indicated.

7. ***Significant, major***. Indicating that the consequences from a given action are obvious to most observers and, in most cases, can be readily measured.

8. ***Warranted***. Indicating that some accepted threshold or set of conditions has been met. As used in this *Guide*, "warranted" may apply to either objective or subjective evaluations. When the "warranting" criteria have been met, this indicates that the designer should consider implementing the recommended treatment; meeting the "warranting" criteria does not indicate that the treatment is required.

3-1.03 Acronyms

The following acronyms are used throughout this *Guide*:

1. ***AASHTO***. American Association of State Highway and Transportation Officials.

2. ***FHWA***. Federal Highway Administration.

3. ***TRB***. Transportation Research Board.

4. ***MUTCD***. *Manual of Uniform Traffic Control Devices*.

5. ***NCHRP***. National Cooperative Highway Research Program.

6. ***HCM***. *Highway Capacity Manual*.

7. ***FEMA***. Federal Emergency Management Administration

3-2 HIGHWAY SYSTEMS

3-2.01 Functional Classification System

Functional classification is the grouping of highways by the character of service they provide. The two primary factors in functionally classifying highways and streets are access to property and travel mobility. The geometric design criteria and procedures presented in this *Guide* are based on the functional classification system, which includes the following:

1. ***Freeways***. The freeway is the highest level of arterial. These facilities are characterized by full control of access, high design speeds and a high level of driver comfort and safety.

2. ***Arterials***. Arterial highways are characterized by high-volume roadways which provide linkage between major cities and towns and developed areas, capable of attracting travel over long distances. Basically, they provide service to interstate and intercounty travel demand. The arterial system typically provides for high travel speeds and the longest trip movements. The degree of access control on an arterial may range from full control (freeways) to entrance control on, for example, an urban arterial through a densely developed commercial area.

3. ***Collectors***. Collector routes are characterized by a roughly even distribution of their access and mobility functions. These routes gather traffic from lesser facilities and deliver it to the arterial system. Traffic volumes and speeds will typically be lower than those of arterials.

4. ***Local Roads and Streets***. All public roads and streets not classified as arterials or collectors will have a local classification. Local roads and streets are characterized by many points of direct access to adjacent properties and have a relatively minor role in accommodating mobility. Speeds and traffic volumes are usually low.

3-2.02 Federal-Aid System

The Federal-aid system consists of those routes within Maine which are eligible for the categorical Federal highway funds. The Department, working with the local governments and in cooperation with FHWA, has designated the eligible routes. United States Code, Title 23, describes the applicable Federal criteria for establishing the Federal-aid system.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 implemented a major realignment of the Federal-aid system. The following sections briefly describe the Federal-aid system created by ISTEA. Figure 3-1 summarizes the system and ISTEA funding eligibility.

National Highway System

The National Highway System (NHS) is a system of those highways determined to have the greatest national importance to transportation, commerce and defense in the United States. It consists of the Interstate highway system, logical additions to the Interstate system, selected other principal arterials, and other facilities which meet the requirements of one of the subsystems within the NHS. Specifically, the NHS includes the following subsystems (note that a specific highway route may be on more than one subsystem):

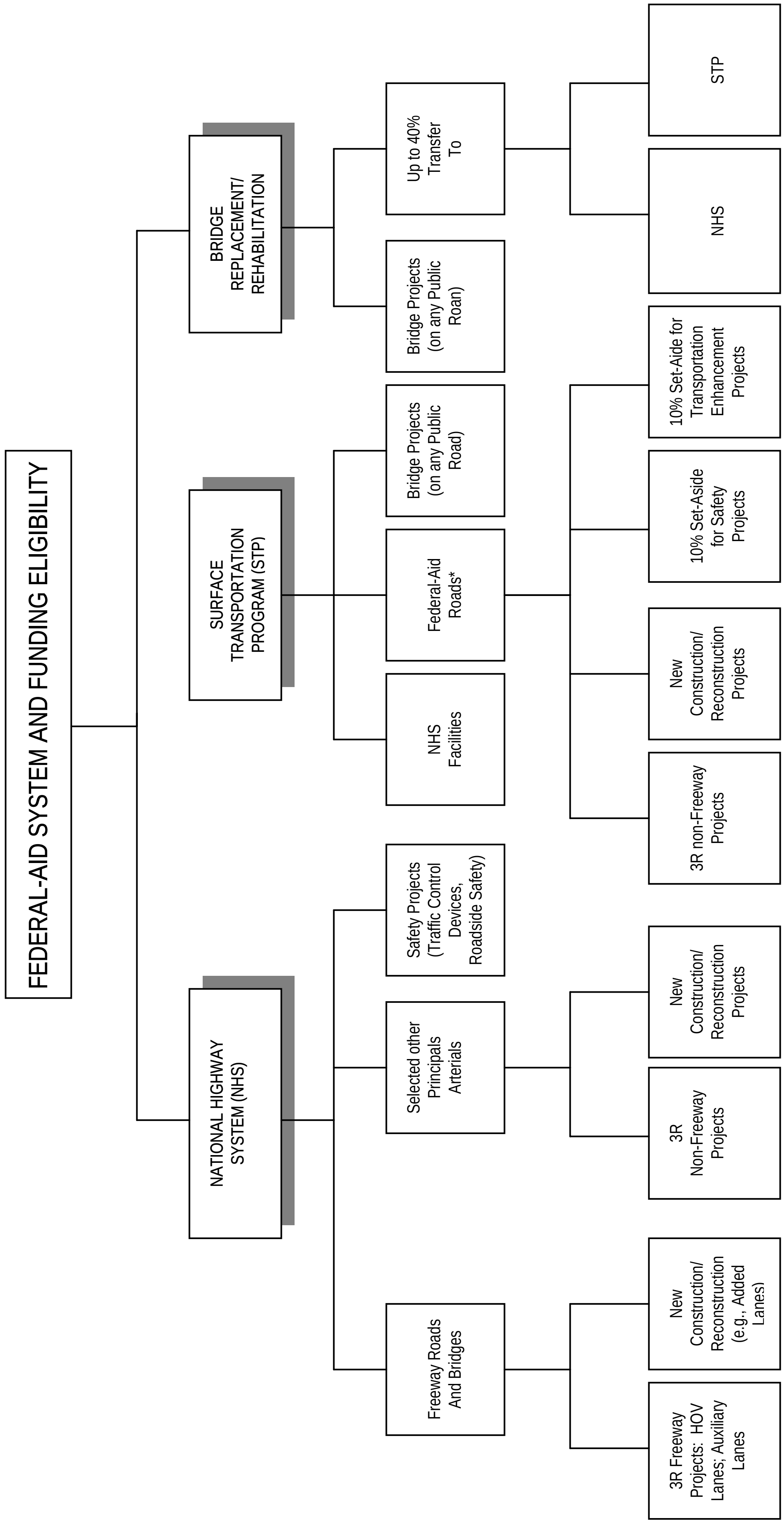
1. ***Interstate.*** The current Interstate system of highways retains its separate identity within the NHS. There are also provisions to add kilometers to the existing Interstate subsystem.

2. ***Other Principal Arterials***. These are highways in rural and urban areas that provide access between an arterial and a major port, airport, public transportation facility or other intermodal transportation facility.

3. ***Strategic Highway Network.*** This is a network of highways that are important to the United States' strategic defense policy and which provide defense access, continuity and emergency capabilities for defense purposes.

4. ***Major Strategic Highway Network Connectors***. These are highways that provide access between major military installations and highways which are part of the Strategic Highway Network.

To properly manage the NHS, the FHWA has mandated that each State highway agency develop and implement several management systems for those facilities on the NHS. These include management systems for pavements, bridges, traffic monitoring, congestion and safety.



* Includes all Non-NHS Arterials, all Major Collectors and all Minor Urban Collectors.

Note: This is the Federal-Aide system as established by the Intermodal Surface Transportation Efficiency Act of 1991

FEDERAL-AID SYSTEM

Figure 3-1

Surface Transportation Program

The Surface Transportation Program (STP) is a category of Federal-aid funds for any public road not functionally classified as a minor rural collector or a local road or street. The STP replaced a portion of the former Federal-aid primary system and replaced all of the former Federal-aid secondary and urban systems, and it includes some collector routes which were not previously on any Federal-aid system. Collectively, these are called Federal-aid Roads. In addition, bridge projects using STP funds are not restricted to Federal-aid roads but may be used on any public road. Transit capital projects are also eligible under the STP program.

The basic objective of the STP is to provide Federal funds for improvements to facilities not considered to have significant national importance with a minimum of Federal requirements for funding eligibility.

Bridge Replacement and Rehabilitation Program

Because of the nationwide emphasis on bridges, the Bridge Replacement and Rehabilitation Program (BRRP) has retained its separate identity within the Federal-aid program. BRRP funds are eligible for work on any bridge on a public road regardless of its functional classification.

3-3 TRAFFIC VOLUME CONTROLS

3-3.01 Definitions

1. ***Average Annual Daily Traffic (AADT).*** The total yearly volume in both directions of travel divided by the number of days in the year.

2. ***Average Daily Traffic (ADT).*** The traffic volume in both directions of travel in a time period greater than one day and less than one year divided by the number of days in that time period. Although incorrect, ADT is sometimes used interchangeably with AADT.

3. ***Design Hourly Volume (DHV).*** The one-hour volume in both directions of travel in the design year selected for determining the highway design. The DHV is typically the 30th highest hourly volume within the design year.

4. ***Level of Service (LOS).*** A qualitative concept which has been developed to characterize acceptable degrees of congestion. In the *Highway Capacity Manual*, the qualitative descriptions of each level of service (A to F) have been converted into quantitative measures for the capacity analysis for each highway element. This includes:

   a. freeway mainline segments,
   b. weaving areas,
   c. freeway mainline/ramp junctions,
   d. freeway ramps,
   e. two-lane, two-way rural highways,
   f. multilane rural highways (other than freeways),
   g. signalized intersections,
   h. unsignalized intersections, and
   i. urban/suburban arterials.

5. ***Capacity.*** The maximum number of vehicles which can reasonably be expected to traverse a point or uniform section of a road during a given time period under prevailing roadway, traffic and control conditions. The time period most often used for analysis is 15 minutes. "Capacity" technically corresponds to LOS E.

6. ***Directional Distribution (D).*** The division, by percent, of the traffic volume in each direction of travel during the DHV, ADT or AADT.

7. ***Traffic Composition (T).*** A factor which reflects the percentage of heavy vehicles (trucks, buses and recreational vehicles) in the traffic stream during the DHV, ADT or AADT.
8. ***(Design) Service Flow Rate.*** The maximum hourly vehicular volume which can pass through a highway element at the selected level of service. The basic intent of a highway capacity analysis is to ensure that the DHV does not exceed the calculated design service volume of the highway element when considering the prevailing roadway, traffic and control conditions.
9. ***Density***. The number of vehicles occupying a given length of lane, averaged over time. It is usually expressed as vehicles per mile per lane (vpmpl).
10. ***Peak-Hour Traffic***. The highest number of vehicles found to be passing through a highway element during 60 consecutive minutes.
11. ***Peak-Hour Factor (PHF).*** A ratio of the volume occurring during the peak hour to the maximum rate of flow during a given time period within the peak hour. Typically, this is 15 minutes.

3-3.02 Selection of Design Year and DHV

A highway should be designed to accommodate the traffic volumes that might occur within the life of the facility under reasonable maintenance. This involves projecting the traffic conditions for a selected future year. Recommended design years based on the project scope of work are presented in Table 3-1. These are measured from the expected construction completion date.

3-3.03 Capacity Analysis

The highway mainline, intersection or other highway element should be designed to accommodate the design hourly volume (DHV) at the selected level of service. This involves adjusting the various highway factors which affect capacity until the proposed design has a design service flow rate which equals or exceeds the DHV.

Chapter Seven presents the criteria for level of service (LOS) for new construction and reconstruction projects based on functional class and urban/rural location. Chapter Eleven provides LOS criteria for 4R freeway projects, rehabilitation non-freeway projects and restoration/resurfacing non-freeway projects. The LOS and DHV should be used with the detailed methodologies and procedures in the *Highway Capacity Manual* to conduct the capacity analysis

Project Scope of Work	**Design Year[1]**
New Construction/Reconstruction (All Functional Classes)	20 Years
4R Freeway	20 Years
Rehabilitation (non-freeway)	20 Years
Restoration/Resurfacing (non-freeway)	10 Years

[1] Design year is measured from the expected construction completion date.

RECOMMENDED PROJECT DESIGN YEAR
(Capacity Analyses)

Table 3-1

3-4 SPEED (Definitions)

1. ***Design Speed***. Design speed is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern. The assumed design speed should be a logical one with respect to the topography, the adjacent land use and the functional classification of highway. Chapter Seven presents the design speed criteria for new construction and reconstruction projects. Chapter Eleven provides the design speed criteria for 4R freeway projects, rehabilitation non-freeway projects and restoration/resurfacing non-freeway projects.

   In addition, for new construction/reconstruction projects, the selected design speed should equal or exceed the anticipated posted/ regulatory speed limit of the facility after construction. See Chapter Eleven for a discussion on the relationship between design speed and posted speed limit for 3R projects on non-freeways.

2. ***Running Speed***. Running speed is the average speed of a vehicle over a specified section of highway. It is equal to the distance traveled divided by the running time (the time the vehicle is in motion). The average running speed is the distance summation for all vehicles divided by the running time summation for all vehicles.

3. ***85th-Percentile Speed***. The 85th-percentile speed is the speed below which 85 percent of the vehicles travel on a given highway. The most common application of the value is its use as one of the factors for determining the posted, legal speed limit of a highway section. In most cases, the field measurements for the 85th-percentile speed will be conducted during off-peak hours.

4. ***Posted Speed Limit***. The posted speed limit is based on an engineering and traffic investigation conducted after each Department project is completed. The Traffic Engineering Division within the Bureau of Maintenance and Operations conducts the study on all public roads. The selection of a posted speed limit is based on several factors, although the 85th-percentile speed will usually serve as the maximum speed limit.

3-5 ACCESS CONTROL (Definitions)

Access control is the condition where the government exercises its authority to control the right of abutting owners to have access to and from the public highway. The following definitions apply:

1. ***Controlled Access***. A controlled access highway is one on which priority is given to through traffic by providing access only at grade separation interchanges with selected public roads. Abutting property owners have no right of direct access. The freeway is the most common type of controlled access highway.

2. ***Limited Access.*** A limited access highway is one on which priority is given to through traffic, but a few at-grade intersections and private driveway connections may be allowed.

3. ***Entrance Control.*** Entrance control, or control by regulation, is exercised by the Department or other public agency to determine where private interests may have access to and from the public road system. Abutting property owners are permitted access to the street or highway; however, the location, number and geometrics of the access points will be governed by driveway and entrance policies. Driveway design criteria are discussed in detail in Chapter Eight.

3-6 PROJECT SCOPE OF WORK

The project scope of work will reflect the basic intent of the highway project and will determine the overall level of highway improvement. This will be documented in the Transportation Investment and Planning Report. This decision will determine which criteria in the *Maine Highway Design Guide* apply to the project. The following descriptions are intended to provide general definitions for the project scope of work.

1. ***New Construction on New Location (All Functional Classes).*** New horizontal and vertical alignment on new location is considered new construction. The tables of geometric design criteria in Chapter Seven provide the basic criteria for new construction.

2. ***Reconstruction (Non-Freeways).*** One of the primary factors which will characterize this scope of work will be the extent of the improvements to the pavement structure. If a new pavement structure (from the subgrade up) will be constructed for more than half of the project length, this will typically be considered a reconstruction project. Reconstruction of an existing non-freeway may also include significant drainage improvements, the addition of travel lanes and/or significant changes to the existing horizontal and vertical alignment, but essentially within the existing highway corridor. These projects will often require right-of-way acquisitions.

   The primary reason to perform reconstruction is that the existing facility (e.g., its pavement structure or traffic capacity) cannot accommodate its current or future traffic demands or because the existing alignment is deficient. Because of the level of work for reconstruction, the design of the project should be determined by the criteria for new construction. Therefore, the tables in Chapter Seven will apply.

3. ***3R Projects (Non-Freeways)***. 3R (rehabilitation, restoration and resurfacing) projects are primarily intended to extend the service life of the existing facility and to enhance highway safety. In addition, 3R projects should make improvements to the existing geometrics, where practical. 3R work on an existing non-freeway is work essentially within the existing alignment. Right-of-way acquisition will usually be limited takings, easements and grading rights. Typical improvements for 3R projects may include:

   a. pavement resurfacing, pavement rehabilitation or pavement reconstruction (up to half of project length);

   b. lane and shoulder widening;

   c. flattening an occasional horizontal or vertical curve;

d. widening the roadside clear zone;

e. flattening side slopes;

f. converting an existing median to a continuous two-way left-turn (CTWLT) lane;

g. adding a truck-climbing lane;

h. revising the location, spacing or design of existing entrances along the mainline;

i. adding or removing parking lanes;

j. adding curbs and islands for entrance control and sidewalks;

k. relocating utility poles;

l. upgrading guardrail to meet current safety criteria;

m. drainage improvements; and/or

n. intersection improvements (e.g., adding turn lanes, flattening turning radii, channelization, corner sight distance improvements, etc.).

For the application of geometric design criteria, 3R projects are subdivided as follows:

a. Rehabilitation. These projects may involve significant improvements to the pavement structure, including a new pavement structure (from the subgrade up) for up to half of the project length. In general, rehabilitation projects warrant the consideration of more significant improvements to the geometric design than restoration/resurfacing projects.

b. Restoration/Resurfacing. These projects are usually intended to resurface, restore or rehabilitate the existing pavement. Geometric design improvements are usually only included to correct obvious deficiencies on the existing highway.

Chapter Eleven presents the Department's geometric design criteria for 3R non-freeway projects.

4. ***4R Projects (Freeways).*** 4R projects (resurfacing, restoration, rehabilitation and/or reconstruction) on existing freeways are primarily intended to extend the service life of

the existing facility, to enhance highway safety and to make improvements to the existing geometrics, where practical. Typical improvements for 4R projects may include:

a. pavement resurfacing, rehabilitation or reconstruction;
b. widening the roadside clear zone;
c. flattening side slopes;
d. improvements to interchange gore areas;
e. regrading median ditch plugs;
f. upgrading guardrail to meet current safety criteria;
g. drainage improvements;
h. addition of travel lanes or auxiliary lanes;
i. flattening a horizontal or vertical curve;
j. lengthening existing acceleration or deceleration lanes;
k. realigning or widening an existing ramp; and/or
l. upgrading signing to meet current MUTCD criteria.

Chapter Eleven presents the Department's criteria for 4R freeway projects.

5. ***Spot Improvements (Non-Freeways).*** Spot improvements are intended to correct an identified deficiency at an isolated location. The deficiency may be related to structural, geometric, safety, drainage or traffic control problems. These projects are not intended to provide a general upgrading of the highway, as are projects categorized as new construction, reconstruction, 3R or 4R. Two types of spot improvements are:

   a. safety improvements at isolated locations, and

   b. bridge improvement projects funded by the Highway Bridge Replacement and Rehabilitation Program.

Chapter Eleven discusses the Department's criteria for the geometric design of spot improvement projects.

3-7 CONTROLLING DESIGN CRITERIA/DESIGN EXCEPTIONS

3-7.01 Federal-Aid Projects

The FHWA has identified "controlling" design criteria for all Federal-aid projects on the National Highway System (NHS). These criteria are for those highway design elements which are judged to be the most critical indicators of a highway's safety and its overall serviceability. The following presents the controlling design criteria:

1. design speed,
2. lane widths,
3. shoulder width
4. cross slopes,
5. bridge widths,
6. structural capacity,
7. horizontal alignment,
8. superelevation
9. stopping sight distance,
10. vertical alignment,
11. maximum grades,
12. minimum vertical clearances;
13. horizontal clearance.

Any controlling design element in an applicable project which does not meet the Department's criteria must be approved as a design exception by FHWA. This only applies to Federal-aid projects on the NHS; it does not, for example, apply to STP-funded projects not on the NHS. However, it will be necessary to obtain an internal Department exception on projects where FHWA approval is not required.

A special note is necessary for the application of the stopping sight distance (SSD) criteria to, for example, horizontal and vertical curves. Section 4-1.01 presents SSD criteria for freeways (Table 4-1) and for non-freeways (Table 4-2). These tables present SSD values corrected for grade. However, for the purpose of identifying the "controlling" criteria, the level SSD value will be used. Therefore, the design exception process will only apply when the proposed design does not provide at least the level SSD value at, for example, a crest vertical curve.

Chapters Seven and Eleven present the Department's tables of geometric design criteria for all project scopes of work, functional classes and urban/rural location. The designer will note that the FHWA controlling design criteria are designated by an asterisk in each table. This provides a convenient summarization of the numerical criteria which apply to a project under design.

3-7.02 Internal Department Application

The *Urban and Arterial Highway Design Guide* presents criteria on many aspects of highway design in addition to the FHWA controlling design criteria. In general, designers are responsible for meeting all design criteria in the *Guide* considering, of course, the practicality of their application to a project or specific site. In addition, where desirable and minimum values are presented, the designer should provide the desirable values if reasonable; the minimum values should only be used where the desirable values cannot be obtained without unreasonable impacts.

Section 3-7.01 presents the list of controlling design criteria. Where a proposed project will not meet the Department's criteria for one or more of these elements, the following procedure will apply:

1. The Project Manager will prepare a written justification explaining why the Department's criteria will not be met.

2. The Program Manager will review and, if in agreement, approve the proposed design.

This procedure applies to all projects whether or not FHWA approval is required.

Where the proposed project design will not meet the Department's criteria in the *Highway Design Guide* for design elements other than controlling design criteria, the designer should discuss this informally with his/her Project Team and gain the Team's verbal approval. On consultant-designed projects where the Department's criteria will not be met, the consultant's project designer will notify the Department informally and gain the Department's verbal approval. This will be addressed as part of the consultant's normal project coordination activities with the Department.

3-7.03 Documentation

See Table 3-2 for the Department's requirements for documenting the applicable design criteria for a proposed project (Form HD-06).

HIGHWAY DESIGN DOCUMENTATION REQUIREMENTS
(Form HD-06)

PROJECT LOCATION: ________________________________ ROUTE: ____________

P.I.N.:_______________ DESIGNER:______________________________

GIVEN

SCOPE: ___ New Construction/Reconstruction ___ Rehabilitation
Restoration/Resurfacing ___ 4R ___ Spot

DESIGN CRITERIA: ___ National Highway ___ State

FUNCTIONAL CLASS: ___ Urban ___ Rural
Freeway ___ Arterial ___ Collector ___ Local

V_{posted} (m/h) = ___ AADT = ____ DHV = _____ 18 kip = __________

REQUIRED

	Design	Minimum	Maximum
V (m/h) =	___________	___________	___________
Slope $_{T.L.}$ =	___________	___________	___________
*W_{lane} (ft) =	___________	___________	___________
*$W_{shoulder}$ (ft) =	___________	___________	___________
R_{min} =	___________	___________	___________
e =	___________	___________	___________
SSD (ft) =	___________	___________	___________
G_{max}(%) =	___________	___________	___________
V.Cl. =	___________	___________	___________

COMMENTS

* Check for any corridor requirements and/or history that may govern widths.

Table 3-2

CHAPTER FOUR

VERTICAL ALIGNMENT

Volume I

- Highway Design Guide - National Standards

December 2004

Chapter Four

TABLE OF CONTENTS

Page

Chapter Four

VERTICAL ALIGNMENT

4-1 SIGHT DISTANCE

Sight distance is the length of approaching highway which is visible to the driver. When the horizontal alignment is on tangent, the available sight distance is determined by the profile of the highway. On a horizontal curve and level grade, available sight distance is determined by the rate of curvature and the roadside clearance (see Chapter Five). Where a combination of horizontal and vertical curves is present, horizontal curvature, vertical curvature and roadside clearance will all determine the availability of sight distance along the highway.

4-1.01 Stopping Sight Distance

1. ***Definition***. Stopping sight distance (SSD) is the sum of the distance traveled during driver perception/reaction time (2.5 seconds) and the distance traveled while braking to a stop.

2. ***Criteria***. SSD values are presented in Tables 4-1. The SSD values provided in the table are based on the longitudinal gradient at the site of application. These values represent the minimum distance which should be available to the driver; the designer should provide greater distances, if practical. Note that the grade-adjusted SSD values will only apply to crest vertical curves (see Section 4-2.03).

   The designer should note that the application of the grade-adjusted SSD values on crest vertical curves assumes a worst-case condition. The need for additional braking distance would occur if the "object" is located at the point of vertical tangency (PVT) which would result in vehicular braking action on the downgrade portion of the crest vertical curve.

3. ***Controlling design criteria***. SSD is a controlling design criteria (see Section 3-7). To determine if a design exception is necessary, the level roadway SSD criteria will apply.

4. ***Measurement***. Stopping sight distance is measured from the driver's eye 3.5 ft above the pavement to a 2 ft height of object.

Design Speed (mph)	Downgrades (ft)			Level (ft)
	-9%	*-6%*	*-3%*	*0%*
20	125	120	115	115
25	175	165	160	155
30	225	215	205	200
35	290	270	260	250
40	355	335	315	305
45	430	400	380	360
50	510	475	450	425
55	595	555	520	495
60	690	640	600	570
65	785	730	685	645
70	890	825	770	730

Notes:

1. For design speeds of 50 mph or higher, no grade adjustment is necessary for downgrades 1% or flatter.
2. For design speeds less than 50 mph, no grade adjustment is necessary for downgrades 2% or flatter.
3. For downgrades intermediate between columns, use a straight-line interpolation to calculate SSD.
4. Grade adjustments apply to crest vertical curves; they do not apply to sag vertical curves. See Section 4-2 for application of SSD to vertical curves. See Sections 5-2 and 5-3 for SSD application to horizontal curves.

STOPPING SIGHT DISTANCE

Table 4-1

4-1.02 Decision Sight Distance

1. ***General Application***. Drivers may be required to make decisions where information is difficult to perceive or where unexpected maneuvers are required. These are areas of concentrated demand where the roadway elements, traffic volumes and traffic control devices may all compete for the driver's attention. This may increase the required driver perception/reaction time. Examples of these locations include freeway exits, freeway lane drops and traffic signals on rural highways. The designer will use his/her judgment to determine which locations warrant decision sight distance.

2. ***Criteria***. Table 4-2 provides values for decision sight distance. Note that the application depends upon the type of maneuver and on rural/urban location.

3. ***Measurement***. The distance is measured from a 3.5-ft height of eye to a 2-ft height of object.

Design Speed (mph)	Decision Sight Distance for Avoidance Maneuver (ft)				
	A	*B*	*C*	*D*	*E*
30	220	490	450	535	620
35	275	590	525	625	720
40	330	690	600	715	825
45	395	800	675	800	930
50	465	910	750	890	1030
55	535	1030	865	980	1135
60	610	1150	990	1125	1280
65	695	1275	1050	1220	1365
70	780	1410	1105	1275	1445

Application

Avoidance Maneuver A: *Stop on rural road.*
Avoidance Maneuver B: *Stop on urban road.*
Avoidance Maneuver C: *Speed/path/direction change on rural road.*
Avoidance Maneuver D: *Speed/path/direction change on suburban road.*
Avoidance Maneuver E: *Speed/path/direction change on urban road.*

DECISION SIGHT DISTANCE

Table 4-2

4-1.03 Passing Sight Distance

1. ***General***. Passing sight distance is the distance needed by a passenger car to safely pass another passenger car. This consideration is limited to two-lane, two-way highways.

2. ***Criteria***. Passing sight distance values are provided in Table 4-3.

3. ***Application***. The designer, where practical, should provide passing sight distance over a high proportion of the highway length. This may involve adjustments to the horizontal and vertical alignment, or additional lanes may be necessary in restricted areas.

4. ***Measurement***. Passing sight distance is measured from a 3.5-ft height of eye to a 3.5-ft height of object.

5. ***No-Passing Zones***. The percent of "no-passing zones" is a significant adjustment to the level-of-service calculations (capacity) for a general two-lane highway segment. (See the *Highway Capacity Manual*). The designer should realize, however, that the criteria for determining pavement markings for no-passing zones is based on the MUTCD. Although related, these criteria differ from the passing sight distance criteria used in highway design.

Design Speed (mph)	Minimum Passing Sight Distance (ft)
20	710
25	900
30	1090
35	1280
40	1470
45	1625
50	1835
55	1985
60	2135
65	2285
70	2480

PASSING SIGHT DISTANCE

Table 4-3

4-2 VERTICAL ALIGNMENT

4-2.01 Terrain (Definitions)

1. ***Level***. Highway sight distances are either long or could be made long without major construction expense.

2. ***Rolling***. The natural slopes consistently rise above and fall below the roadway grade and, occasionally, steep slopes present some restriction to the desirable highway alignment.

3. ***Mountainous***. Longitudinal and transverse changes in elevation are abrupt, and benching and side hill excavation are frequently required to provide the desirable highway alignment.

For highway design application, the majority of the projects in Maine will be classified as rolling terrain.

4-2.02 Grades

Maximum Grades

Chapters Seven and Eleven present the Department's criteria for maximum grades based on functional classification, urban/rural location, type of terrain, design speed and project scope of work. The maximum grades should be used only where absolutely necessary. Grades much flatter than maximum normally should be used.

Minimum Grades

1. ***Curbed Streets***. The centerline profile on highways and streets with curb should have a minimum gradient of 0.25 percent. Desirably, the minimum gradient will be 0.5 percent.

2. ***Uncurbed Roads***. On highways without curb, level gradients are acceptable on pavements which are adequately crowned to drain laterally. However, it is desirable to provide approximately a 0.25 percent longitudinal grade. This allows for the possibility that the original crown slope will subsequently be altered as a result of swell, consolidation, maintenance operations or resurfacing.

Critical Length of Grade

In addition to the maximum grade, it is necessary to consider the effect of length of grade upon vehicular operation. The gradient in combination with its length will determine the truck speed reduction on upgrades. The following will apply for the critical length of grade:

1. ***Criteria***. Figure 4-1 provides the critical length of grade for a given percent grade and acceptable truck speed reduction. The figure applies to any design speed. For design purposes, the 10 mph speed reduction curve should be used.

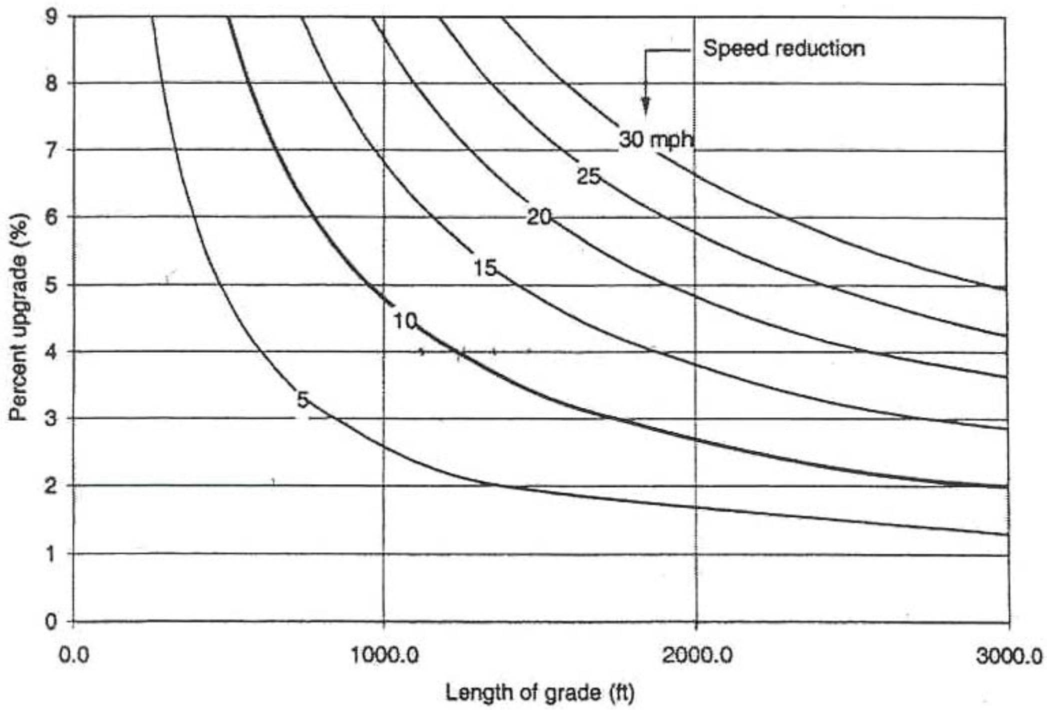
2. ***Momentum Grades***. Where an upgrade is preceded by a downgrade, trucks will often increase speed to make the climb. A speed increase of 5 mph on moderate downgrades (3-5%) and 10 mph on steeper downgrades (6-8%) of sufficient length are reasonable adjustments. These can be used in design to allow the use of a higher speed reduction curve in Figure 4-1.

3. ***Measurement***. A vertical curve will be a part of the length of grade. Figure 4-2 illustrates how to measure the length of grade for the purpose of determining the critical length of grade from Figure 4-1.

4. ***Application***. If the critical length of grade is exceeded, the designer should either flatten the grade, if practical, or should evaluate the need for a truck-climbing lane (see Section 4-2.04).

5. ***Highway Types***. The critical length of grade criteria applies equally to two-lane or multilane highways. However, it has greater significance on two-lane highways because an overtaking car may not be able to pass a slow-moving truck. This consideration is reflected in the capacity analysis for truck-climbing lanes.

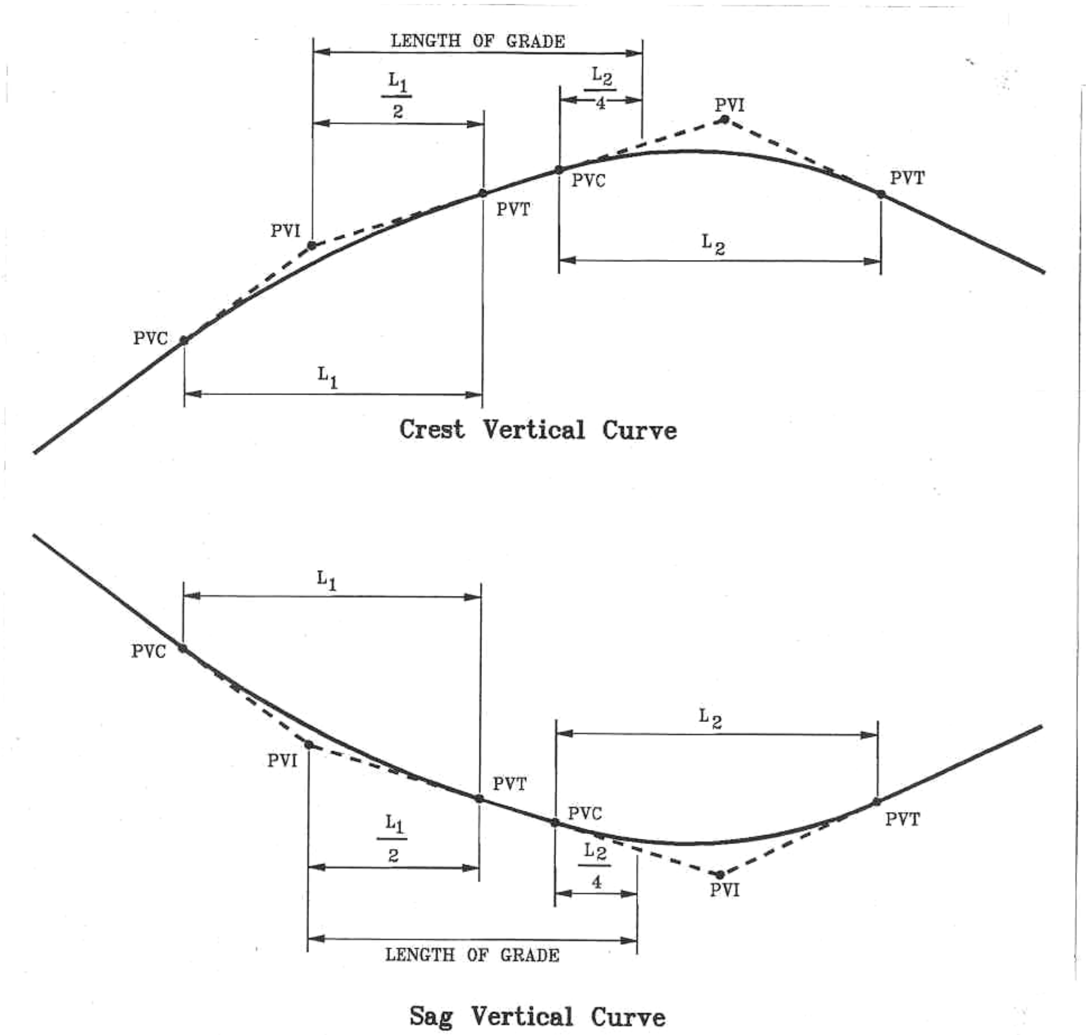
6. ***Example Problems***. Examples 1, 2 and 3 illustrate the use of Figure 4-1 to determine the critical length of grade. In the examples, the use of subscripts 1, 2, etc., indicate the successive gradients and lengths of grade on a highway segment.



1. Typically the 10 mph curve will be used.
2. See examples 1, 2 and 3 for use of figure.

CRITICAL LENGTH OF GRADE

Figure 4-1



Notes:

1. For vertical curves where the two grades are in the same direction, 50% of the curve length will be part of the length of grade.
2. For vertical curves where the two grades are in opposite directions, 25% of the curve length will be part of the length of grade.

MEASUREMENT FOR CRITICAL LENGTH OF GRADE

Figure 4-2

* * * * * * * * * *

Example 1

Given: $G_1 = 0\%$
$G_2 = +4\%$
$L_2 = 1500$ ft (PVI to PVI)

Problem: Determine if the critical length of grade is exceeded.

Solution: Figure 4-1 yields a critical length of grade of 1200 ft for a 10mph speed reduction. The length of the grade (L_2) exceeds this values, and the designer should flatten the grade, if practical, or evaluate the need for a climbing lane.

Example 2

Given: $G_1 = 0\%$
$G_2 = +5\%$
$L_2 = 330$ ft (PVI to PVI)
$G_3 = +2\%$
$L_3 = 660$ ft (PVI to PVI)

Problem: Determine if the critical length of grade is exceeded for the combination of grades G_2 and G_3.

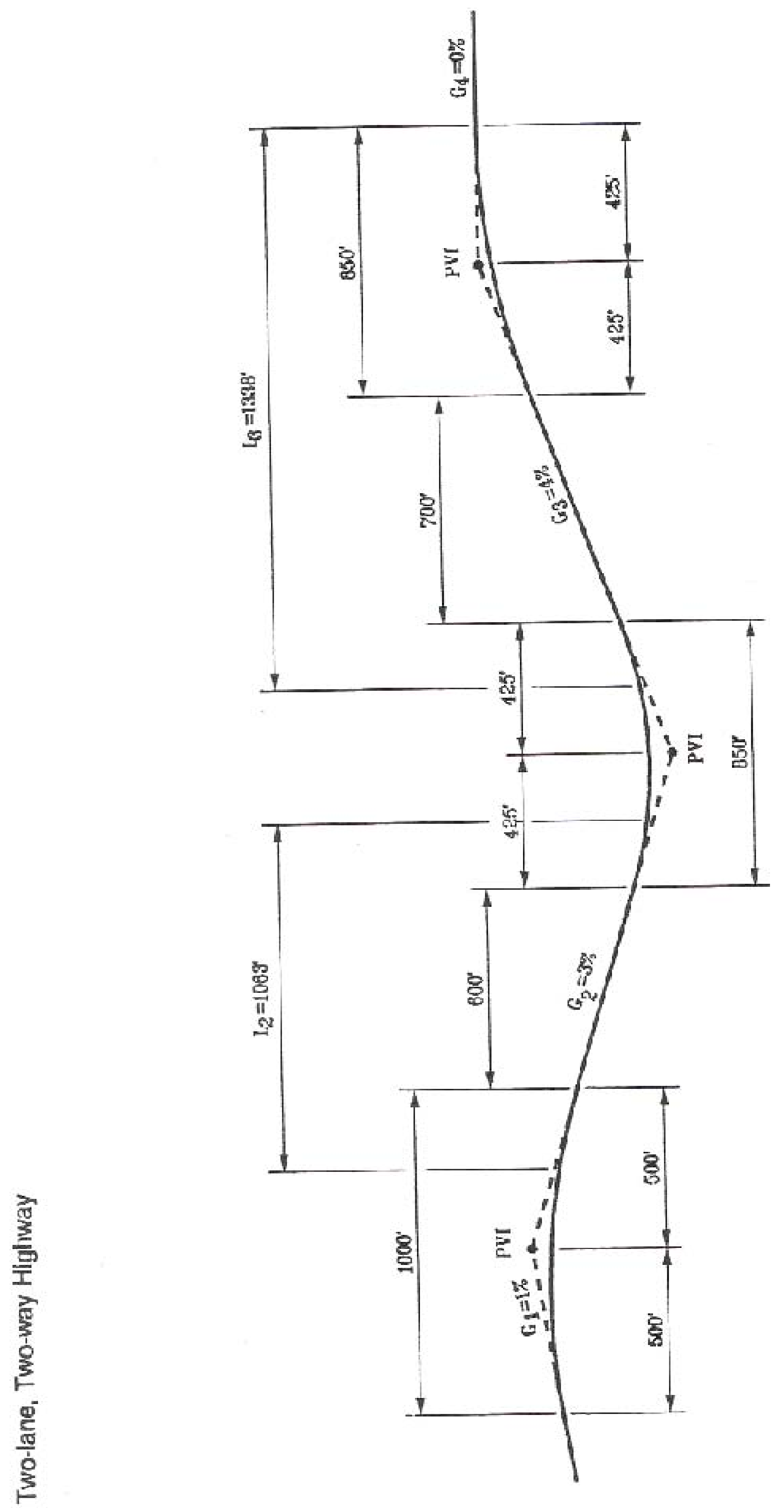
Solution: Using Figure 4-1, G_2 yields a truck speed reduction of approximately 4 mph. G_3 yields approximately 3.5 mph. The total of 7.5 mph is less than the allowable 10 mph. Therefore, the critical length of grade is not exceeded.

Example 3

Given: Figure 4-3 illustrates the vertical alignment on a two-lane rural highway.

Problem: Determine if the critical length of grade is exceeded for G_2 or G_3.

Solution: Figure 4-2 presents the criteria for determining the length of



CRITICAL LENGTH OF GRADE CALCULATIONS (Example 3)

Figure 4-3

$$L2 = \frac{1000}{4} + 600 + \frac{850}{4} = 1063 \text{ ft}$$

$$L3 = \frac{850}{4} + 700 + \frac{850}{2} = 1338 \text{ ft}$$

Read into Figure 4-1 for G_2 (3%) and find a critical length of grade of 1750 ft. L_2 is less than this value and, therefore, the critical length of grade is not exceeded.

Read into Figure 4-1 for G_3 (4%) and find a critical length of grade of 1200 ft. L_3 exceeds this value. However, the designer can assume a 5 mph increase in truck speed for the 3% "momentum" grade (G_2) which precedes G_3. Therefore, read into Figure 4-1 for G_3 (4%) and a 15 mph speed reduction curve and find a critical length of grade of 1850 ft. Assuming the benefits of the momentum grade, then, leads to the conclusion that the critical length of grade is not exceeded.

* * * * * * * * * *

4-2.03 Vertical Curves

Definitions

1. ***Vertical Curve***. Vertical curves have the shape of a parabola and are used to produce a gradual change between tangent grades.

2. ***Point of Vertical Intersection (PVI).*** The PVI is the point where the extension of two tangent grades intersect.

3. ***Point of Vertical Curvature (PVC)***. The PVC is the point at which the tangent grade ends and the vertical curve begins.

4. ***Point of Vertical Tangency (PVT).*** The PVT is the point at which the vertical curve ends and the tangent grade begins.

5. ***Grade Slopes (G_1 or G_2).*** The grade slope is the rate of slope between two adjacent PVI's expressed as a percent. The numerical value for percent is the vertical rise or fall in feet for each 100 feet of horizontal distance. Upgrades in the direction of stationing are identified as plus (+). Downgrades are identified as minus (-).

6. ***Algebraic Difference (A).*** The value of A is the algebraic difference in percent between two tangent grades.

7. ***Length of Vertical Curve (L).*** L is the horizontal distance in feet from the PVC to the PVT.

Mathematical Computation

Figure 4-4 illustrates a typical vertical curve. The vertical offset from the tangent to any point on the curve varies as the square of the horizontal distance from the end of curve. Curves which are offset below the tangents are crest vertical curves, and those which are offset above tangents are sag vertical curves.

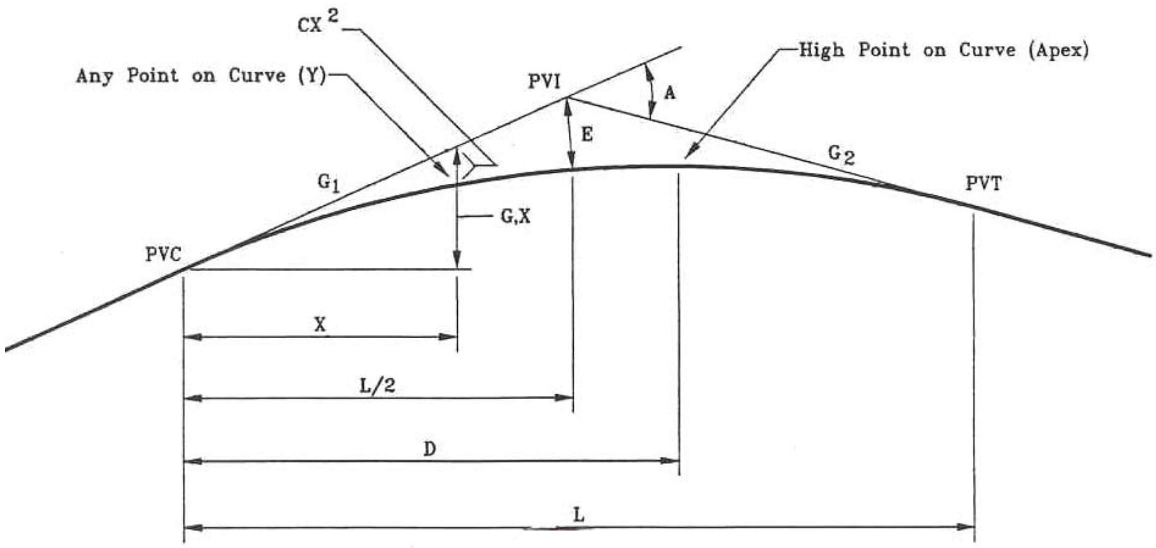
Crest Vertical Curves

The following factors should be considered in the design of crest vertical curves:

1. ***Stopping Sight Distance***. The principal control in the design of crest vertical curves is to ensure that, at a minimum, stopping sight distance (SSD) is available. Desirably, of course, the vertical curve will be designed to provide the largest, practical amount of sight distance. A 3.5 ft height of eye and a 2 ft height of object are used in the design of crest vertical curves. This yields the following procedure for determining the length of a crest vertical curve:

   a. ***Determine the SSD***. The SSD will be selected from Table 4-1. At a minimum, the level SSD criteria will be used. If practical, the grade-adjusted SSD should be used. If so, the designer must consider whether or not the roadway is two-way or one-way. Figure 4-5 illustrates the correct application of the grade correction to a crest vertical curve based on a two-way or one-way operation.

   b. ***Calculate Curve Length***. The following equations will determine the length of the crest vertical curve based on the selected SSD:



1. Legend

X = horizontal distance from PVC to any point on curve (feet)
Y = elevation above sea level of finished grade at any point on curve (feet)
L = horizontal length of curve from PVC to PVT (feet)
D = distance from PVC to high point on crests or low point of sags
G_1, G_2 = the percent grades of the two tangents (%). "Upgrades" in the direction of stationing are denoted "positive" (+) ; "Downgrades" in the direction of stationing are denoted as "negative" (-) .

A = $G_2 - G_1$ = algebraic difference in grades
E = AL / 800 = external offset from the vertical curve to PVI at L / 2 (feet)

2. Elevation Calculations (Known: El_{PVI}, G_1, G_2, L, Sta_{PVI})

A. PVC information:

$Sta_{PVC} = Sta_{PVI} - L / 200$

$El_{PVC} = El_{PVI} - G_1L / 200$

B. PVT information:

$Sta_{PVT} = Sta_{PVI} + L / 200$

$El_{PVT} = El_{PVI} + G_2L / 200$

C. PVC to PVI:

$Y = (G_1X / 100) - CX^2 + El_{PVC}$

$C = A / 200(L)$

D. PVI to PVT:

$Y = [G_2 (L - X) / 100] - C(L - X)^2 + El_{PVT}$

$C = A / 200(L)$

3. Distance (D) to High Point (Crests) or Low Point (Sags).

$D = LG_1 / (G_1 - G_2)$ where: D, L, G_1, G_2 are defined above.

TYPICAL VERTICAL CURVE

Figure 4 - 4

Highway ______________________ **Date** ______________________
Town ______________________ **Engineer** ______________________
Project ______________________ **Sheet No.** ______________________

G_1 = ______________________ El_{PVI} = ______________________
G_2 = ______________________ El_{PVC} = ______________________
L = ______________________ El_{PVT} = ______________________

PVC to PVI

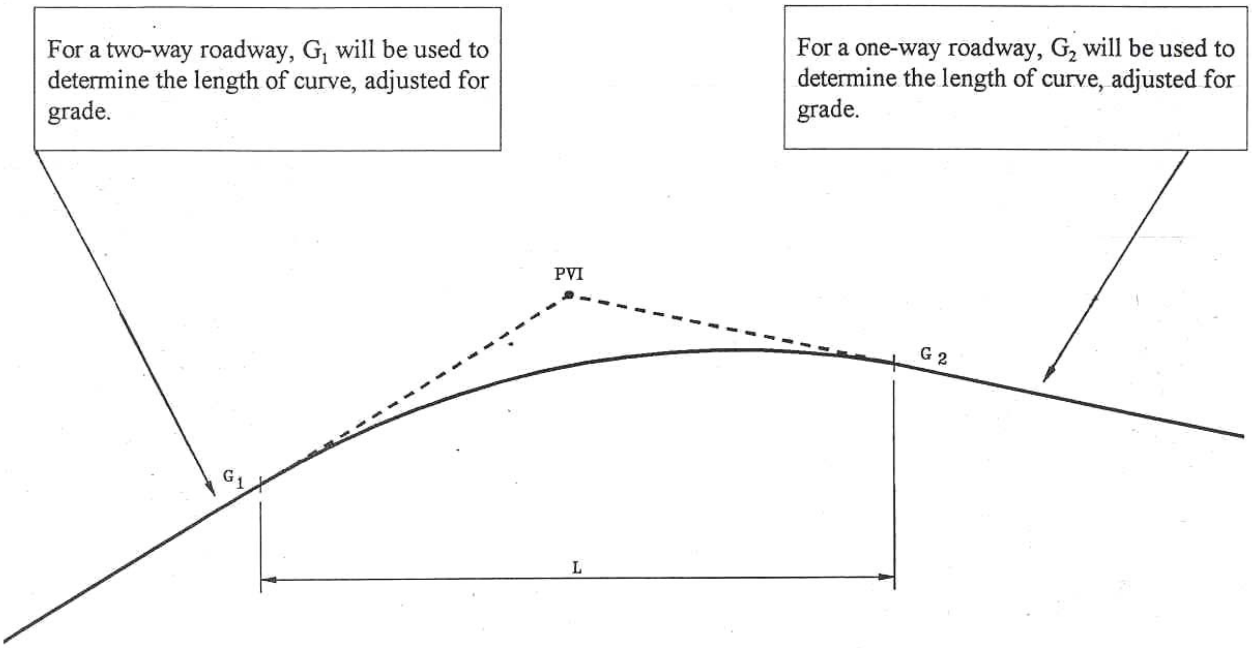
Station	X	$G_1 \frac{X}{100}$	Elev. of Tangent Grade	CX^2	Offset	Elev. of Finished Grade

PVI to PVT

Station	X	$\frac{G_2(L - X)}{100}$	Elev. of Tangent Grade	$C(L-X)^2$	Offset	Elev. of Finished Grade

TABULATION OF GRADIENT ELEVATION
(Vertical Curve)

Table 4-5



Notes: 1. G_1 is steeper than G_2.
2. For one-way roadway, traffic is moving from left to right in figure.

APPLICATION OF GRADE ADJUSTMENT
(Crest Vertical Curves)

Figure 4-5

$$L = \frac{AS^2}{2158} \qquad (S < L)$$

$$L = 2S - \frac{2158}{A} \qquad (S > L)$$

where: S = available stopping sight distance, feet
L = length of crest vertical curve, feet
A = algebraic difference in grades, percent

Figure 4-6 provides a graphical representation of the relationship between the algebraic difference (A), the selected design speed (V) and the length of curve (L).

c. Application. The calculated length of vertical curve should be adjusted to fit field conditions (e.g., driveway controls).

* * * * * * * * * *

Example 4

Given: V = 60 mph
2-lane, 2-way highway
Reconstructed crest vertical curve
$G_1 = +4\%$
$G_2 = -3\%$

Problem: Determine the length of crest vertical curve assuming both the level SSD and grade-adjusted SSD.

Solution: From Table 4-1:

level SSD = 570 ft
grade-adjusted SSD (4%) = 613 ft

(***Note*** Because this is a 2-way highway, the 4% grade will govern for determining the grade-adjusted SSD.)

Assuming S < L: A = G2 - G1 = -3 - 4 = -7 or just 7

$$L = \frac{AS^2}{2158} = \frac{(7)(570)^2}{2158} = 1054 \text{ ft (level SSD)}$$

$$L = \frac{AS^2}{2158} = \frac{(7)(613)^2}{2158} = 1219 \text{ft (grade - adjusted SSD)}$$

The value for level SSD (L = 1054 ft) can be read (approximately) from Figure 4-6a Crest Vertical Curves.

* * * * * * * * * *

2. ***Passing and Decision Sight Distance***. Tables 4-2 and 4-3 provide values for passing sight distance and decision sight distance. Occasionally, it may be warranted to provide these values on crest vertical curves (see Sections 4-1.02 and 4-1.03).

3. ***Minimum Length***. The minimum length (in feet) of a new or reconstructed crest vertical curve, regardless of sight distance calculations, is L_{min} = 3 V, where V equals the design speed (mph).

4. ***Drainage Maximum***. Drainage should be considered in the design of vertical curves where curbed sections are used. Drainage problems should not be experienced if the crest vertical curve is sharp enough so that an absolute minimum longitudinal grade of 0.25 percent is reached at a point about 50 ft from either side of the apex. To ensure that this objective is achieved, the length of the vertical curve should be:

   $L \leq 200$ A, where L is in feet.

   For crest vertical curves on curbed sections where this length is exceeded, the drainage design should be more carefully evaluated near the apex.

Sag Vertical Curves

The following factors determine the design of sag vertical curves.

1. ***Headlight Sight Distance***. Headlight sight distance is the primary control in the design of sag vertical curves. At a minimum, curves should be designed to provide headlight sight distance equal to stopping sight distance. The height of headlights is assumed to be 2 feet and the height of object is 0 (pavement surface). These criteria yield the following procedure for determining the length of a sag vertical curve:

a. ***Determine the SSD***. The SSD will be selected from Table 4-1 (Stopping Sight Distance). The level SSD criteria will be used; the grade adjustment does not apply to sag vertical curves.

b. ***Calculate Curve Length***. The following equations will determine the length of the sag vertical curve based on the selected SSD:

$$(S > L) \qquad L = 2S - \left(\frac{400 + 3.5\,(S)}{A} \right)$$

$$(S < L) \qquad L = \frac{A(S^2)}{400 + 3.5\,(S)}$$

where: S = available stopping sight distance, feet
L = length of sag vertical curve, feet
A = algebraic difference in grades, percent

Figure 4-8 provides a graphical representation of the relationship between the algebraic difference (A), the selected design speed (V), and the length of curve (L).

c. ***Application.*** The calculated length of vertical curve should be adjusted to fit field conditions (e.g., driveway controls).

* * * * * * * * * *

Example 5

Given: V = 65 mph
New sag vertical curve
G_1 = - 4%
G_2 = + 2%

Problem: Determine the length of sag vertical curve for the level SSD.

Solution: From Table 4-1: Level SSD = 645 ft

Assuming S < L:

$$L = \frac{AS^2}{400 + 3.5S} = \frac{(6)(645)^2}{400 + 3.5(645)} = 939 \text{ ft}$$

This value can be read (approximately) from Figure 4-6 b Sag Vertical Curves.

2. ***Decision Sight Distance***. Table 4-2 provides values for decision sight distance. Where decision sight distance is warranted on sag vertical curves, these values should be used in the equations to determine the necessary length of curve at the site.

3. ***Comfort Criteria***. On fully lighted sections of highway and where it is impractical to provide the headlight sight distance, it may be warranted to design a sag vertical curve to meet the comfort sag criteria. The length-of-curve equation for the comfort criteria is:

$$L = \frac{AV^2}{46.5}$$

Where: A = algebraic difference in tangent grades, percent
V = design speed, mph

The length of vertical curve required to satisfy comfort criteria is about 50 percent of that required to satisfy the headlight sight distance requirement. Figure 4-8 provides the criteria for the length of sag vertical curves assuming the comfort criteria.

4. ***Minimum Length.*** The minimum length (in feet) of a new or reconstructed sag vertical curve, regardless of sight distance calculations, is $L_{min} = 3V$, where V equals the design speed (mph).

5. ***Drainage Maximum***. On curbed pavements, the drainage criteria for sag vertical curves is the same as that for crest conditions. The design should provide an absolute minimum grade of 0.25 percent within 50 ft of the sag point. To ensure that this objective is achieved, the length of vertical curve should be:

$L \leq 200A$, where L is in feet.

If the length of the sag exceeds this length on a curbed street, the designer should place special emphasis on the drainage design in the sag. Details for the drainage design of sag vertical curves are provided in Chapter Twelve.

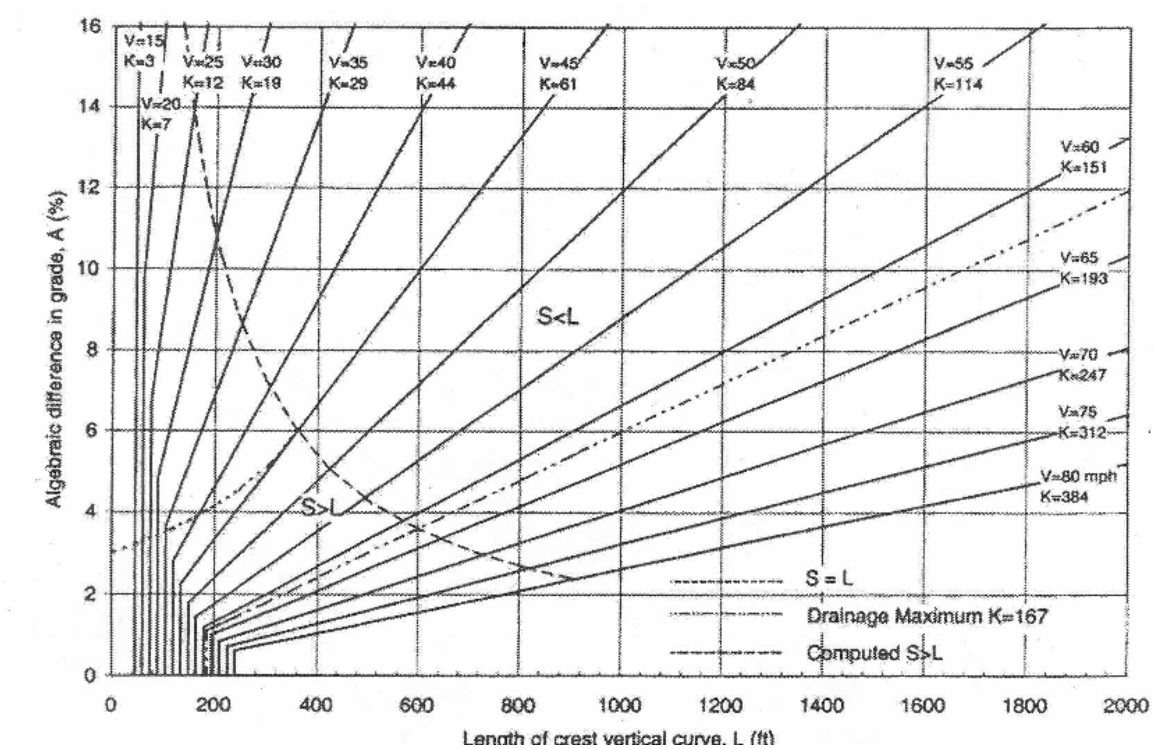


Figure 4-6a Crest Vertical Curves

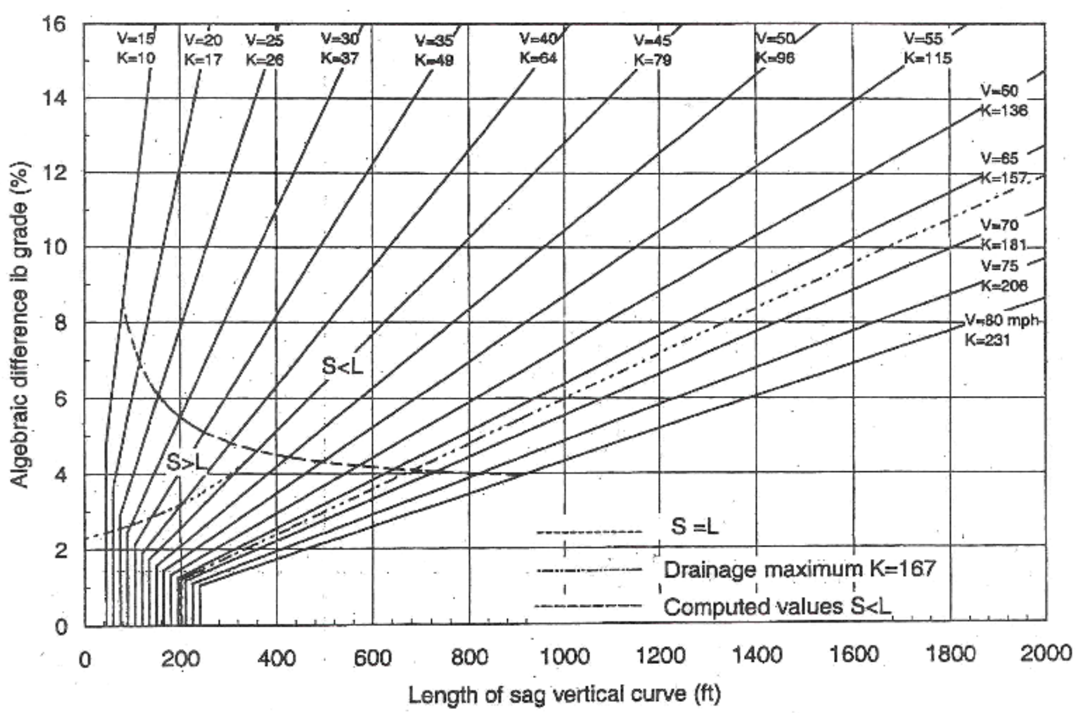
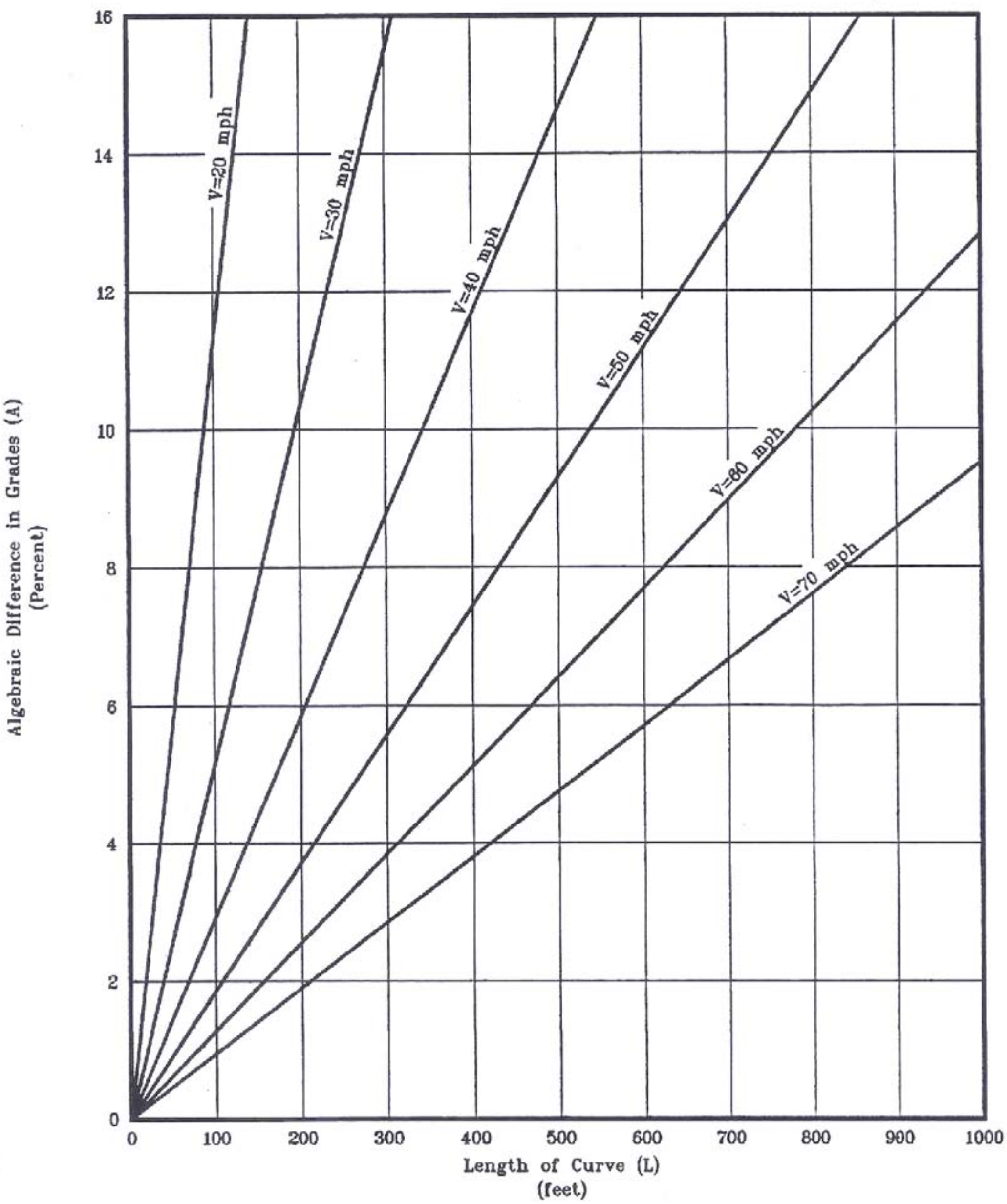


Figure 4-6b Sag Vertical Curves

LENGTH OF VERTICAL CURVES

Figure 4-6



LENGTH OF VERTICAL CURVES
(Comfort Criteria)

Figure 4-7

4-2.04 Truck Climbing Lanes

Climbing lanes can overcome losses in capacity and thereby provide improved operations on grades with both slow trucks and high traffic volumes. The following steps should be used to determine the warrants for a truck climbing lane.

Step 1: Determine the critical length of grade from Figure 4-1 for a given percent grade and acceptable truck speed reduction. If this value is exceeded, a capacity analysis should be conducted.

Step 2: The operational objective is that the level of service (LOS) on the grade should be no worse than one level below that of the remainder of the highway segment. For example, if the approaching highway is operating at LOS B, the grade should operate at LOS C or better. If the capacity analysis determines that the grade will operate below this LOS objective for the DHV without a climbing lane, the designer should consider including a climbing lane if the construction costs and impacts (e.g., environmental, right-of-way) are reasonable. The *Highway Capacity Manual* and AASHTO *A Policy on Geometric Design of Highways and Streets* present the detailed methodologies to conduct a capacity analysis on a grade. Table 4-5 summarizes the design criteria for a truck climbing lane.

Example 6

Given: Figure 4-8 illustrates the highway grade under construction. A capacity analysis has determined that a climbing lane is warranted.

Problem: Develop the details for the truck-climbing lane for the minimum conditions.

Solution: The design for the climbing lane is illustrated in Figure 4-8.
These steps should be followed:

Design Element	Desirable	Minimum
Design Speed	(1)	(1)
Lane Width	Same as approach roadway	Same as approach roadway
Shoulder Width	4 ft	2 ft
Cross Slope on Tangent	Same as adjacent travel lane	Same as adjacent travel lane
Superelevation	(2)	(2)
Beginning of Full-Width Lane	Near the PVT of the grade	To where truck speed is 10 mph below highway design speed (3)
End of Full-Width Lane	To where truck has reached highway design speed	To where truck speed is 10 mph below highway design speed (3), (4)
Minimum Full-Width Length	--	1000 ft
Entering Taper	25:1	150 ft
Exiting Taper	50:1	200 ft

Notes:

1. For design speeds equal to or greater than 55 mph use 55 mph for truck design speed. For less than 55 mph, use the design speed.

2. For horizontal curves to the right, the truck climbing lane will be superelevated the same as the adjacent travel lane. For horizontal curves to the left, the designer will determine the proper Superelevation of the truck climbing lane by reading into Table 5-6 (e_{max} = 6%) for V=30 mph. The maximum difference in cross slope between the travel lane and truck climbing lane is 4 percent.

3. Use Figure 4-9 to determine truck deceleration and acceleration rates.

4. The designer should also consider the available sight distance to the point where the truck will merge back into the through travel lane. At a minimum, this will be stopping sight distance. Desirably, however, the driver will have decision sight distance available to the merging point.

DESIGN CRITERIA FOR TRUCK CLIMBING LANES

Table 4-5

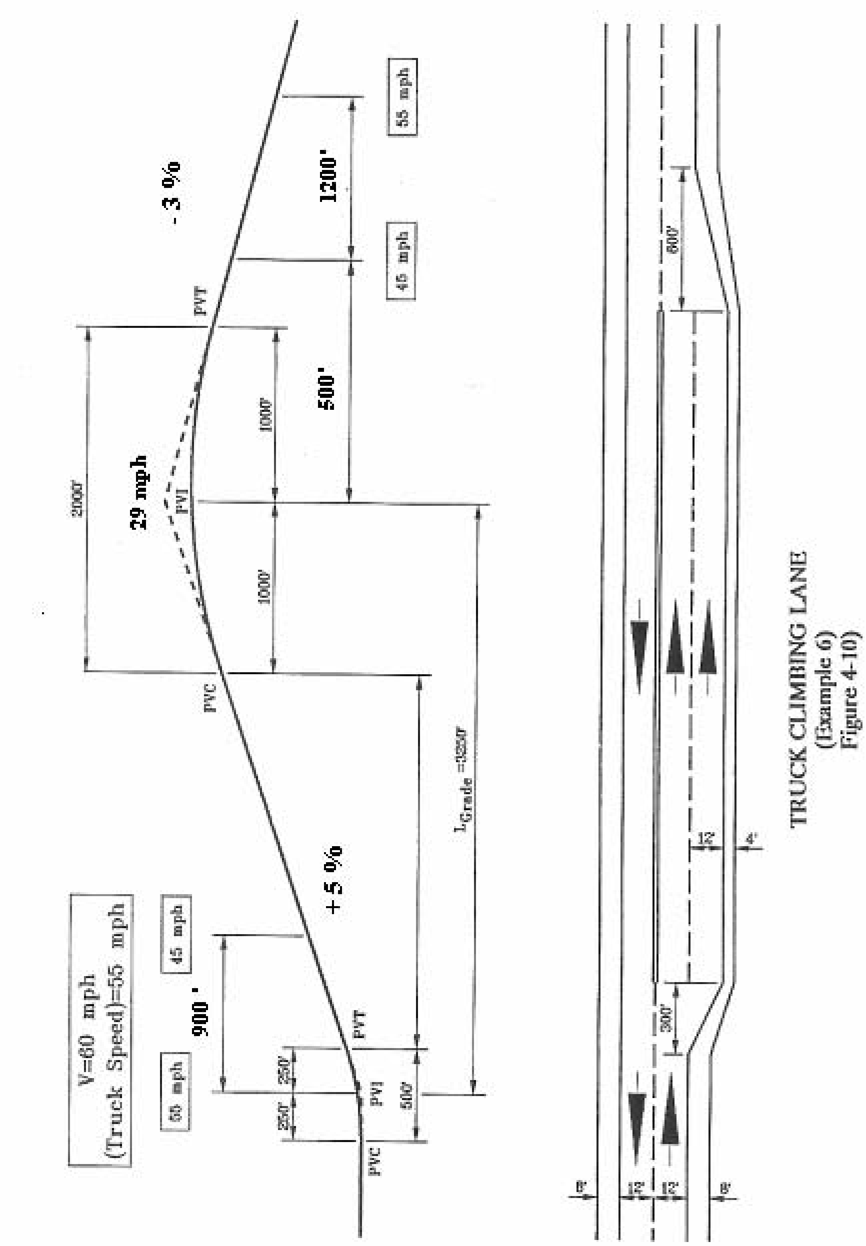
1. ***Length of Grade***. To establish a reference point, grades will be assumed to run from PVI to PVI to analyze a truck-climbing lane. Therefore, the length of the +5% grade is 3250 ft.

2. ***Truck Speed***. For all highway design speeds above 55 mph, the truck speed for analysis will be 55 mph. For design speeds of 55 mph or less, the truck speed will equal the design speed.

3. ***Truck Deceleration***. At a minimum, the full width of the climbing lane will begin where the truck speed has been reduced by 10 mph or, in this example, to 45 mph. Using Figure 4-1 or Figure 4-9 (Note; This figure is based on a start speed of 70 mph), this will occur approximately 900ft from the PVI. The truck speed at the end of the grade (3250 ft) is determined from Figure 4-9. Therefore, the truck speed will be approximately 29 mph when it reaches the PVI.

4. ***Truck Acceleration***. At a minimum, the full width of the climbing lane will extend to a point where the truck has accelerated to 45 mph (10 mph below the 55 mph truck design speed). The designer reads into Figure 4-10 at the 29 mph point on the vertical axis over to the dashed line for -3%. This is at approximately 200 feet along the horizontal axis. The -3% line is followed up to 45 mph, which is approximately 700 feet along the horizontal axis. Therefore, the truck will require approximately 500 feet from the PVI to reach 45 mph. The truck will require approximately an additional 1200 ft to reach 55 mph.

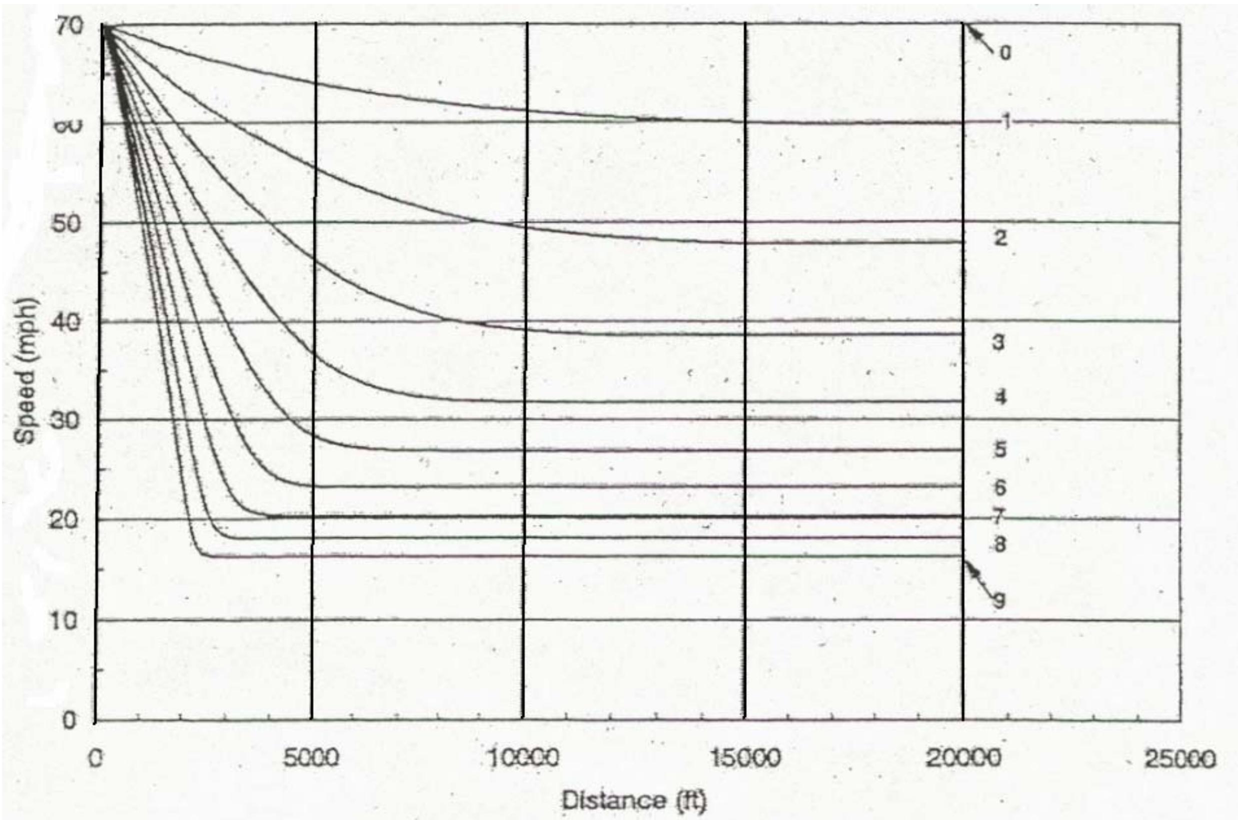
5. ***Design Details***. Figure 4-8 illustrates the design details for the minimum criteria for the climbing lane.



Note: For design speeds above 55 mph, use an initial speed of 55 mph. For design speeds 55 mph and below, use the design speed as the initial speed.

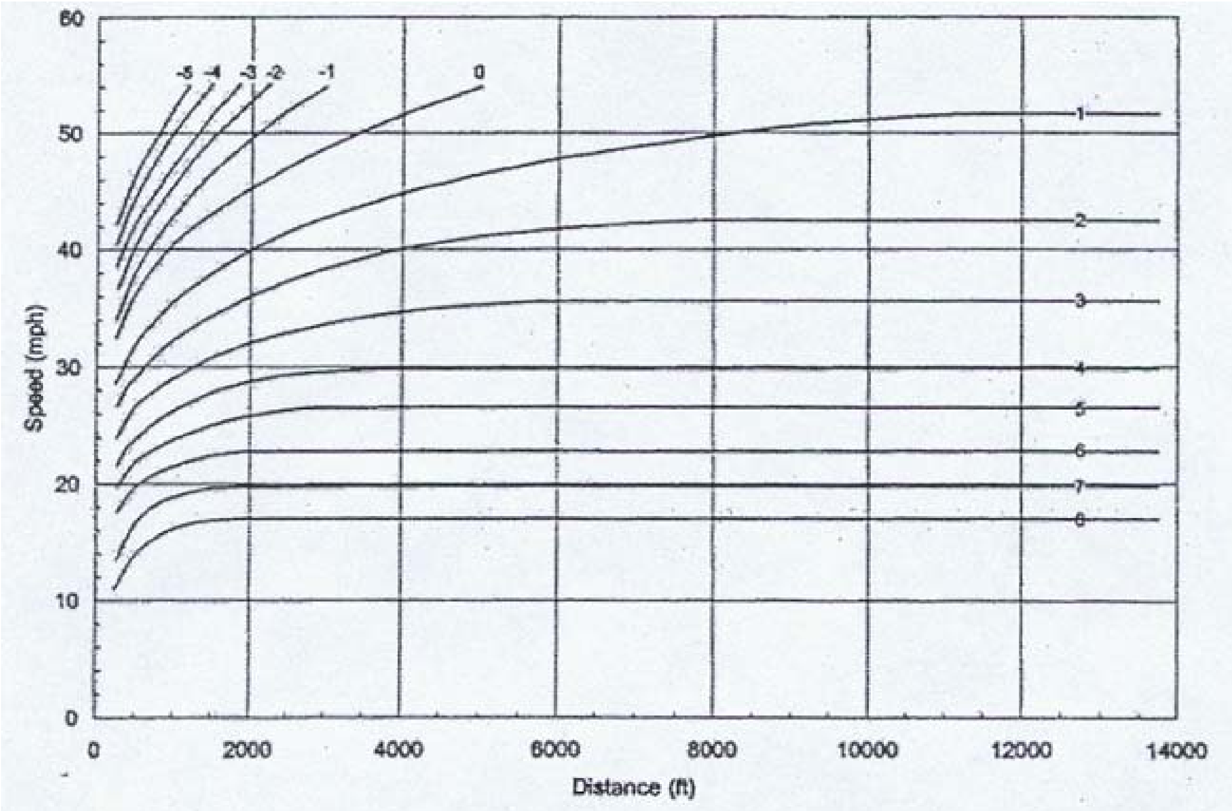
TRUCK CLIMBING LANE
(Example 6)

Figure 4-8



PERFORMANCE CURVES FOR HEAVY TRUCKS
Deceleration (on Percent Upgrades Indicated)

Figure 4-9



PERFORMANCE CURVES FOR HEAVY TRUCK
Acceleration (on Percent Grades Up and Down Indicated)

Figure 4-10

CHAPTER FIVE

HORIZONTAL ALIGNMENT

Volume I

- Highway Design Guide –

National Standards

December 2004

Chapter Five

TABLE OF CONTENTS

Page

Chapter Five

HORIZONTAL ALIGNMENT

Section 5-2 presents the Department's horizontal alignment criteria for all rural highways and high-speed urban highways (V>45 mph). Section 5-3 presents the Department's criteria for horizontal alignment on low-speed urban streets (V≤45 mph).

5-1 DEFINITIONS

1. ***Simple Curve***. A simple curve is that portion of the arc of a circle which achieves the desired deflection without using an entering or exiting transition.

2. ***Compound Curve.*** A compound curve (with deflections in the same direction) is a combination of any number of individual simple curves (e.g., 2-centered or 3-centered) and may be symmetrical or asymmetrical.

3. ***Point of Intersection (PI).*** The PI is the point of intersection of two tangents.

4. ***Point of Curvature (PC).*** The PC is the point of change from tangent to circular curve.

5. ***Point of Tangent (PT).*** The PT is the point of change from circular curve to tangent.

6. ***Deflection Angle (Δ).*** The deflection angle is the intersection angle between the two tangents forming the circular curve (also referred to as the central angle of curve).

7. ***Degree of Curve (D).*** The degree of curve is the central angle which subtends an arc length of 100 feet (arc definition). The maximum degree of curve is a limiting value for a given design speed based on the maximum rate of superelevation and maximum allowable side friction factor.

5-2 RURAL HIGHWAYS AND HIGH-SPEED URBAN HIGHWAYS

5-2.01 Types of Horizontal Curves

Deflectional changes in horizontal alignment may be accomplished by using a simple curve or a compound curve. The following discusses each of the horizontal curvature types.

Simple Curves

Figure 5-1 illustrates a typical simple curve layout. Considering their simplicity and ease of design, survey and construction, the simple curve is the type of curve used most often.

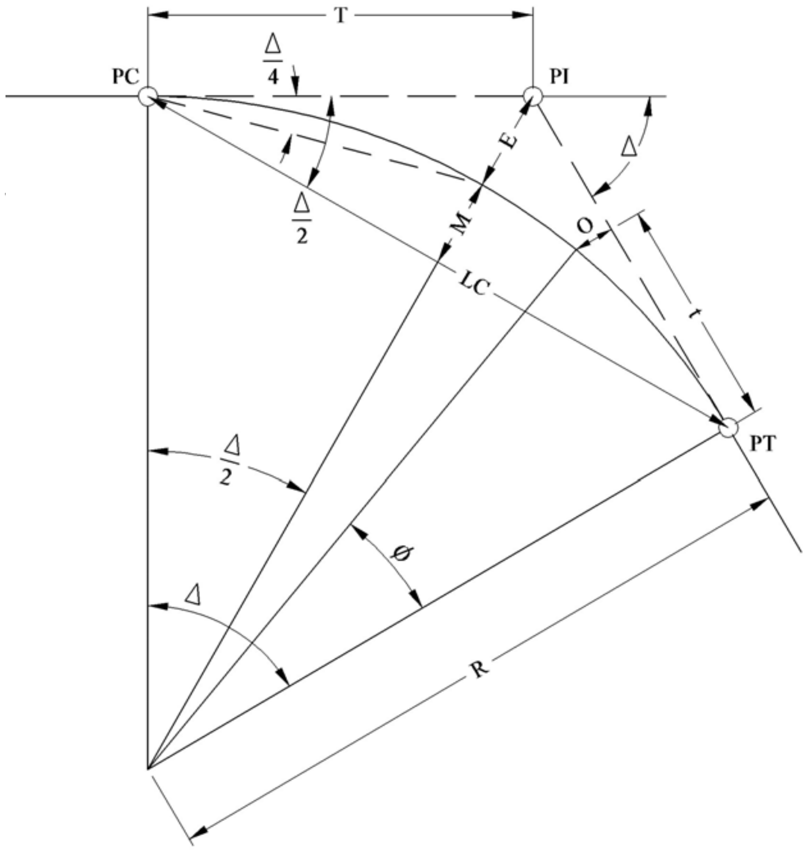
Compound Curves

Compound curves are used to establish alignment where a controlling obstruction cannot be relocated. They may occasionally be used to transition into and out of a simple curve. Table 5-1 provides the suggested criteria for considering a compound curve for transitions where the design speed is 50 mph or higher. Figure 5-2 illustrates the layout of a symmetrical 3-centered compound curve.

When a compound curve is used on a highway main line, the radius of the flatter circular arc (R_1) should not be more than 50 percent greater than the radius of the sharper circular arc (R_2). In other words, $R_1 \leq 1.5\ R_2$. For degree of curve, the equation becomes $D_1 \geq 0.67\ D_2$.

5-2.02 Maximum Degree of Curve

Table 5-2 provides the maximum degree of curve for each design speed on all rural highways and high-speed urban highways. The designer should provide flatter horizontal curves where practical. The designer may also need to provide flatter curvature where the proposed degree of curve will not provide the necessary stopping sight distance for horizontal curves. See Section 5-2.06.



$$R = \frac{5729.5780}{D}$$

$$L = 100\frac{\Delta}{D} = \frac{\Delta R}{57.2958}$$

$$T = R\tan\frac{\Delta}{2}$$

$$E = T\tan\frac{\Delta}{4}$$

$$M = R\left(1 - \cos\frac{\Delta}{2}\right)$$

$$LC = 2R\sin\frac{\Delta}{2}$$

$$O = R - \sqrt{R^2 - t^2}$$

$$O = R\,(1 - \cos\phi)$$

PI = Point of Intersection of tangents
PC = Point of Curvature
PT = Point of Tangency
Δ = Central angle of curve (deflection angle)
D = Degree of curvature
L = Length of curve (ft); arc length from PC to PT
R = Radius of curve (ft)
T = Tangent length (ft) from PC to PI or from PT to PI
E = External distance (ft) from PI to midpoint of circular arc
M = Middle ordinate (ft) connecting midpoints of circular arc and long chord
LC = Long chord (ft) from PC to PT
ϕ = Deflection angle from PT to any point on curve
t = Tangent distance (ft) from PT to any point on curve along tangent
O = Tangent distance (ft) from tangent to any point on curve

TYPICAL SIMPLE CURVE LAYOUT

Figure 5-1

Design Speed (mph)	Consider Compound Curve When
50	R < 1130 ft
55	R < 1455 ft
60	R < 1800 ft
65	R < 2175 ft
70	R < 2775 ft

***Note*:** The limiting Radius (R) suggested for a compound curve is based on 75% of the maximum radius for a given design speed.

SUGGESTED CRITERIA FOR CONSIDERING A COMPOUND CURVE

Table 5-1

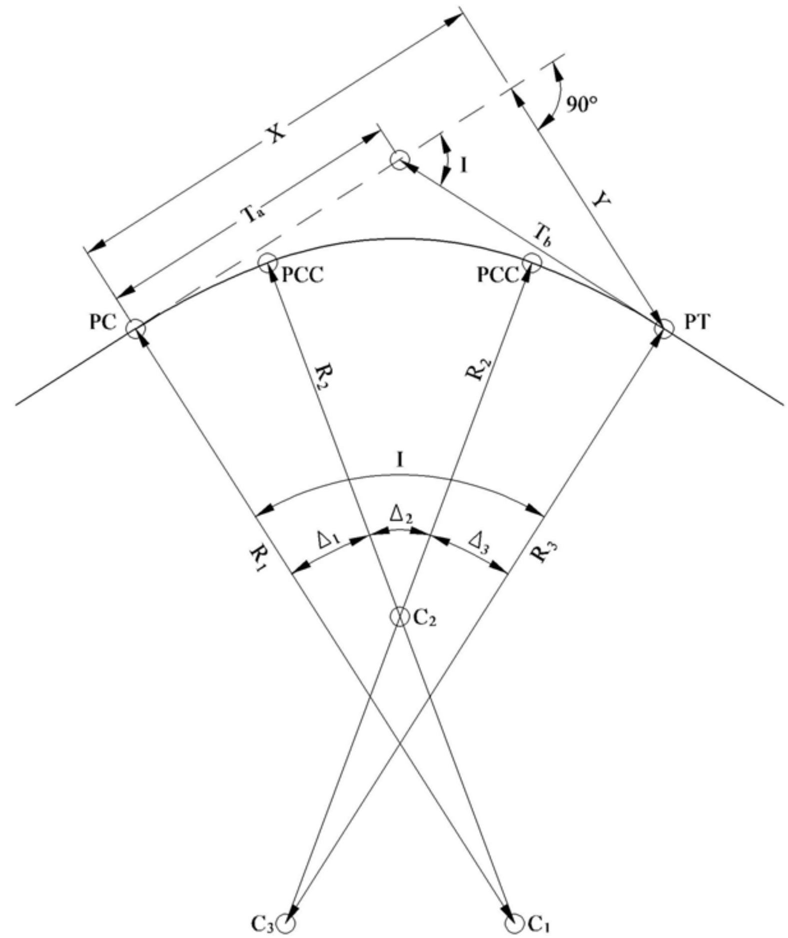
Design Speed (mph)	Minimum Radius (ft)
30	275
40	510
45	660
50	835
55	1065
60	1340
65	1660
70	2050

***Note*:** $e_{max} = 6.0\%$

Minimum Radius
(Rural Highways and High-Speed Urban Highways)

Table 5-2

Equations for Any Two-Centered Compound Curves:		
I	=	Total Deflection Angle = $\Delta_1 + \Delta_2$
X	=	$R_2 \sin I + (R_1 - R_2) \sin \Delta_1$
Y	=	$R_1 - R_2 \cos I - (R_1 - R_2) \cos \Delta_1$
T_b	=	$Y / \sin I$
T_a	=	$X - T_b \cos I$
Equations for Any Three-Centered Compound Curves:		
I	=	Total Deflection Angle = $\Delta_1 + \Delta_2 + \Delta_3$
X	=	$(R_1 - R_2) \sin \Delta_1 + (R_2 - R_3) \sin (\Delta_1 + \Delta_2) + R_3 \sin I$
Y	=	$R_1 - R_3 \cos I - (R_1 - R_2) \cos \Delta_1 - (R_2 - R_3) \cos (\Delta_1 + \Delta_2)$
T_b	=	$Y / \sin I$
T_a	=	$X - T_b \cos I$
Equations for Symmetrical Three-Centered Compound Curve ($R_1 = R_3$; $\Delta_1 = \Delta_3$, as shown in Figure):		
I	=	Total Deflection Angle = $2\,\Delta_1 + \Delta_2$
X	=	$(R_1 - R_2) \sin \Delta_1 + (R_2 - R_1) \sin (\Delta_1 + \Delta_2) + R_1 \sin I$
Y	=	$R_1 - R_2 \cos I - (R_1 - R_2) \cos \Delta_1 - (R_2 - R_1) \cos (\Delta_1 + \Delta_2)$
T_b	=	$Y / \sin I$
T_a	=	$X - T_b \cos I$
Note: $R_1 \leq 1.5\, R_2$		



Note: This is only one example of how a compound curve can be designed.

SYMMETRICAL THREE-CENTERED COMPOUND CURVE

Figure 5-2

5-2.03 Widening of Travelway

Widening of the traveled way may be desirable on the inside edge of horizontal curves to make operating conditions on the curves comparable to those on tangent. This feature may be especially applicable to 3R projects (See Chapter Eleven). The designer should evaluate the need for widening on a case-by-case basis considering the functional class, type of shoulder, traffic volumes, truck volumes and urban/rural location. In some cases, it may be warranted to reduce the shoulder width for the purpose of widening the travel lanes.

Table 5-3 presents design values of travelway widening on highway curves for 2-lane highways. This applies to either 1-way or 2-way operation. A recommended minimum widening of 2 feet should be used. Widening may be warranted in known problem areas (e.g., where inside shoulder has broken up because of traffic), even when not warranted by the criteria in the table.

Widening should be applied to the inside edge of pavement only. Desirably, the transition distance for traveled way widening will equal the superelevation transition length, and it will be applied coincident with the superelevation transition. Figure 5-3 illustrates the application of travelway widening to a horizontal curve. Note also that the figure indicates the proper pavement marking for the curve.

5-2.04 Length of Curve

Calculated vs. Minimum

The length of a horizontal curve is calculated by:

$$L = 100\frac{\Delta}{D} = \frac{\Delta R}{57.2958}$$

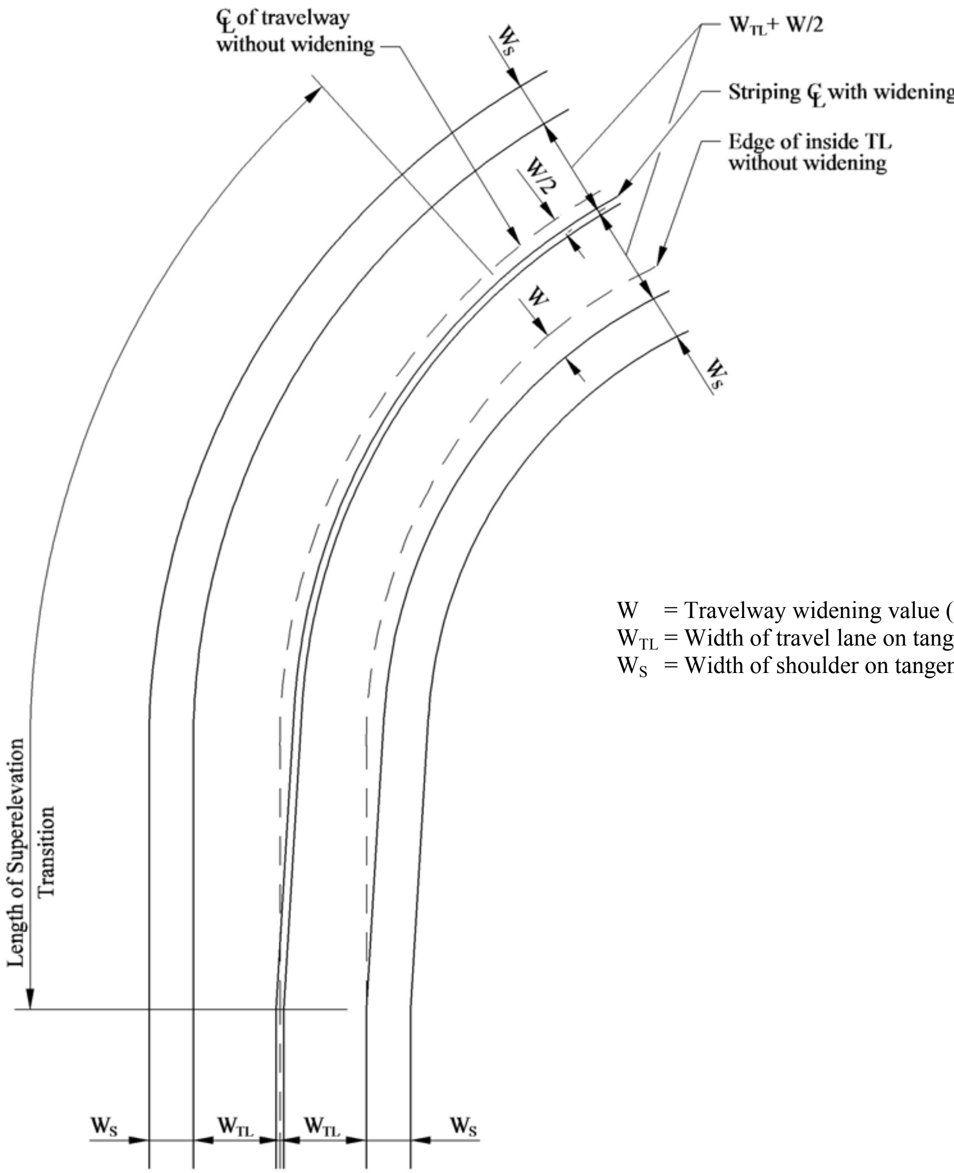
For small deflection angles, the calculated lengths may produce undesirably short curves. For major roads, it is desirable that the length of curve be approximately 15V regardless of the calculated length (V = design speed in mph). The designer should use a flatter degree of curve to achieve the necessary deflection. Table 5-4 presents recommended criteria for the lengths of horizontal curves, and these should be met if practical.

Radius of Curve (ft)	24-ft Travelway Design Speed (mph)							22-ft Travelway Design Speed (mph)							20-ft Travelway Design Speed (mph)						
	30	35	40	45	50	55	60	30	35	40	45	50	55	60	30	35	40	45	50	55	60
7000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0
6000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	2.0
5500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	2.1
5000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	2.1	2.1
4500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	2.1	2.1	2.2
4000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	2.1	2.2	2.2	2.3
3500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	2.1	2.2	2.3	2.3	2.4
3000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	2.1	2.2	2.3	2.4	2.5	2.6
2500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	2.3	2.4	2.5	2.6	2.7	2.8
2000	-	-	-	-	-	-	-	-	-	-	-	-	2.0	2.1	2.4	2.5	2.6	2.7	2.8	3.0	3.1
1800	-	-	-	-	-	-	-	-	-	-	-	2.0	2.1	2.2	2.5	2.6	2.8	2.9	3.0	3.1	3.2
1600	-	-	-	-	-	-	-	-	-	-	2.0	2.2	2.3	2.4	2.7	2.8	2.9	3.0	3.2	3.3	3.4
1400	-	-	-	-	-	-	-	-	2.0	2.1	2.2	2.4	2.5	2.6	2.8	3.0	3.1	3.2	3.4	3.5	3.6
1200	-	-	-	-	-	-	-	2.1	2.2	2.4	2.5	2.7	2.8	2.9	3.1	3.2	3.4	3.5	3.7	3.8	3.9
1000	-	-	-	-	2.0	2.2	2.4	2.4	2.6	2.7	2.9	3.0	3.2	3.4	3.4	3.6	3.7	3.9	4.0	4.2	4.4
900	-	-	2.0	2.1	2.3	2.5		2.6	2.8	3.0	3.1	3.3	3.5		3.6	3.8	4.0	4.1	4.3	4.5	
800	-	2.1	2.2	2.4	2.6	2.8		2.9	3.1	3.2	3.4	3.6	3.8		3.9	4.1	4.2	4.4	4.6	4.8	
700	2.2	2.4	2.6	2.8	3.0			3.2	3.4	3.6	3.8	4.0			4.2	4.4	4.6	4.8	5.0		
600	2.7	2.9	3.1	3.3	3.5			3.7	3.9	4.1	4.3	4.5			4.7	4.9	5.1	5.3	5.5		
500	3.3	3.5	3.7	3.9				4.3	4.5	4.7	4.9				5.3	5.5	5.7	5.9			
450	3.7	3.9	4.1					4.7	4.9	5.1					5.7	5.9	6.1				
400	4.2	4.4	4.7					5.2	5.4	5.7					6.2	6.4	6.7				
350	4.8	5.1	5.3					5.8	6.1	6.3					6.8	7.1	7.3				
300	5.6	5.9						6.6	6.9						7.6	7.9					
250	6.8							7.8							8.8						
200	8.5							9.5							10.5						

Notes:
1. Minimum widening should be 2 ft on all highways.
2. For 3-lane pavements, multiply table values by 1.5.
3. For 4-lane pavements, multiply table values by 2.

DESIGN VALUES FOR WIDENING THE TRAVELWAY ON HIGHWAY CURVES (FT)
(Two-Lane Pavements)

Table 5-3



W = Travelway widening value (see Table 5-3)
W_{TL} = Width of travel lane on tangent
W_S = Width of shoulder on tangent

Notes:

1. Figure applies to both ends of the highway curve.
2. All widening occurs on inside of curve.
3. Solid lines in figure indicate pavement marking.
4. Desirably, the shoulder width will remain constant through the curve. When the shoulder width is decreased for travelway widening, the pavement structure should be increased accordingly in this area of the shoulder.

APPLICATION OF TRAVELWAY WIDENING ON HORIZONTAL CURVES
Figure 5-3

Functional Class	Design Speed (mph)	Deflection Angle (Δ)		
		< 0° 30′	*0° 30′ - 5°*	*> 5°*
Arterials and Freeways	45	(2)	500	675
	50	(2)	500	750
	55	(2)	500	825
	60	(2)	500	900
	65	(2)	500	925
	70	(2)	500	1050
Rural Collector and Local Roads	30-60	(2)	300	500

Notes: 1. The length of the curve in feet, should be its calculated length ($\Delta R/57.2958$) or ($100\ \Delta/D$) or the recommended length in the table, whichever is longer.

2. For $\Delta < 0° 30'$, consider providing no horizontal curve. See discussion in Section 5-2.04

RECOMMENDED MINIMUM LENGTH OF CURVE (FT) (1)
(Rural Highways and High-Speed Urban Highways)

Table 5-4

<u>Sharpest Deflection with No Curve</u>

For a deflection angle less than about 30 minutes, the designer should evaluate the visual impact of not providing a horizontal curve; i.e., allowing the angle point to remain. The top of a crest vertical curve and a signal-controlled intersection are examples of where a small deflection angle may not be visible and may not impact driver response. These types of locations should be evaluated on a case-by-case basis. However, no angle points should be permitted on bridge structures.

5-2.05 Superelevation Development

Definitions

1. ***Superelevation***. Superelevation is the amount of cross slope or "bank" provided on a horizontal curve to help counterbalance the outward pull of a vehicle traversing the curve. The maximum rate of superelevation (e_{max}) depends on several factors including climatic conditions, terrain conditions and type of area (rural or urban).

2. ***Superelevation Transition Length***. The superelevation transition length is the distance required to transition the roadway from a normal crown section to the full superelevation needed. Superelevation transition length is the sum of the tangent runout and superelevation runoff.

    a. ***Tangent Runout***. AASHTO defines tangent runout as the change from a normal crown section to a point where the adverse cross slope of the outside lane or lanes is removed (i.e., the outside lane(s) is level).

    b. ***Superelevation Runoff***. AASHTO defines superelevation runoff as the change in cross slope from the end of tangent runout (adverse crown removed) to a section that is fully superelevated.

3. ***Axis of Rotation.*** The superelevation axis of rotation is the line about which the pavement is revolved to superelevate the roadway. This line will maintain the normal highway profile throughout the curve, and it is known as the construction centerline or control edge.

4. ***Superelevation Rollover***. Superelevation "rollover" is the algebraic difference between the travel lane cross slope and shoulder cross slope on the outside of a horizontal curve.

5. ***Normal Crown (NC).*** The typical cross section on a tangent section (i.e., no superelevation).

6. ***Remove Crown (RC).*** A superelevated cross section which is sloped across the entire traveled way in the same direction and at a rate equal to the typical cross slope on a tangent section (e.g., 2.0%)

Superelevation Rate

The Department has adopted e_{max} = 6.0% for the design of rural highways and high-speed urban highways (V > 45 mph). Table 5-6 provides superelevation rates for various combinations of curvature and design speed.

A horizontal curve with a very small degree of curve does not require superelevation. For a given design speed, the normal crown section (NC) used on tangent sections (2.0%) can be maintained throughout a very flat curve. On sharper curves for the same design speed, a point is reached where a slope across the total pavement width is desirable (RC). Table 5-5 provides the threshold (or maximum) degree of curve for a normal crown section and a remove crown section at various design speeds. Examples 1 and 2 illustrate how to use Tables 5-5 and 5-6 to determine the superelevation rate and cross slope bank for a given degree of curve.

Design Speed (mph)	**Degree of Curve**		
	Normal Crown	***Remove Crown***	***See Table 5-6***
30	R > 3185 ft	3185 ft ≥ R ≥ 2150 ft	R < 2150 ft
35	R > 4140	4140 ≥ R ≥ 2795	R < 2795
40	R > 5290	5290 ≥ R ≥ 3580	R < 3580
45	R > 6485	6485 ≥ R ≥ 4465	R < 4465
50	R > 7995	7995 ≥ R ≥ 5370	R < 5370
55	R > 9550	9550 ≥ R ≥ 6485	R < 6485
60	R > 11090	11090 ≥ R ≥ 7640	R < 7640
65	R > 12735	12735 ≥ R ≥ 8595	R < 8595
70	R > 14325	14325 ≥ R ≥ 9825	R < 9825

DEGREE OF CURVE FOR NORMAL CROWN SECTION AND REMOVE CROWN SECTION (Rural Highways and High-Speed Urban Highways)

Table 5-5

D	R (ft)	V=30 (mph)	V=35 (mph)	V=40 (mph)	V=45 (mph)	V=50 (mph)	V=55 (mph)	V=60 (mph)	V=65 (mph)	V=70 (mph)
0° 15'	22,918	NC	NC	NC	NC	NC	NC	NC	NC	NC
0° 30'	11,459	NC	NC	NC	NC	NC	NC	NC	RC	RC
0° 45'	7,639	NC	NC	NC	NC	RC	RC	2.1	2.4	2.6
1° 00'	5,730	NC	NC	NC	RC	RC	2.4	2.7	3.0	3.3
1° 30'	3,820	NC	RC	RC	2.5	2.8	3.3	3.7	4.1	4.6
2° 00'	2,865	RC	RC	2.5	3.0	3.5	4.0	4.5	5.0	5.5
2° 30'	2,292	RC	2.5	3.0	3.5	4.0	4.6	5.1	5.6	5.9
3° 00'	1,910	2.3	2.9	3.4	4.0	4.5	5.0	5.5	5.9	**R_{max} = 2050**
3° 30'	1,637	2.6	3.2	3.8	4.3	4.8	5.4	5.8	6.0	
4° 00'	1,432	2.9	3.5	4.1	4.7	5.2	5.7	6.0	**R_{min} = 1660**	
5° 00'	1,146	3.4	4.0	4.6	5.1	5.6	5.9	**R_{min} = 1340**		
6° 00'	955	3.8	4.4	5.0	5.5	5.9	**R_{min} = 1065**			
7° 00'	819	4.1	4.7	5.3	5.8	**R_{minn} = 835'**				
8° 00'	716	4.3	5.0	5.6	6.0					
9° 00'	637	4.6	5.3	5.8	**R_{min} = 660'**					
10° 00'	573	4.8	5.5	5.9						
11° 00'	521	5.0	5.7	6.0						
12° 00'	477	5.2	5.8	**R_{min} = 510'**						
13° 00'	441	5.4	5.9							
14° 00'	409	5.5	6.0							
16° 00'	358	5.8	**R_{min} = 380'**							
18° 00'	318	5.9								
20° 00'	286	6.0								
21° 00'	273	6.0								
		R_{min} = 275'								

Key:

R = Radius of Curve

V = Design Speed, mph

e = Superelevation Rate (%)

NC = Normal Crown (2.0% crown slope)

RC = Remove Crown (superelevate at normal crown slope)

SUPERELEVATION RATE
(Rural Highways and High-Speed Urban Highways)

Table 5-6

Example 1

Given: Design speed = 50 mph
Radius = 4045 feet
Tangent Cross Slope = 2.0%

Problem: Determine the superelevation rate.

Solution: For intermediate superelevation rates between the radius provided in Table 5-6, use a straight-line interpolation.

From Table 5-5, when R < 5370 ft at v = 50 mph, use table 5-6

From Table 5-6, when R = 4045 ft, it is between;
5730 ft where e = RC (2% in this case) and 3820 ft where e = 2.8%

Therefore, when R = 4045 ft e = what?:

$$e = \left(\frac{4045 - 5730}{3820 - 5730} \right) (2.8 - 2.0) + 2.0$$

$$e = (0.88)(0.8) + 2.0$$

$$e = 0.2704$$

Use e = 2.7%.

Example 2

Given: Design speed = 50 mph
Radius = 2292 ft
Two-lane roadway
12 ft travel lanes

Problem: Determine "B," the elevation differential between the edge of travel lanes.

Solution: From Table 5-6, the superelevation rate is 4.0% = 0.040 ft/ft.

The total horizontal distance from low side of bank to high side of bank is 24 ft.

B_{Total} = (0.040 ft/ft) (24 ft) = 0.96 ft = 11.52 in.

B/2 = 5.76 in.

This distance should be rounded to the nearest ¼". Therefore, the elevation differential will be 5¾" from the crown point to the high side edge of travel lane and 5¾" from the crown point to the low side edge of travel lane.

* * * * * * * * * *

Superelevation Transition

Superelevation should be introduced and removed uniformly over a length adequate for a given design speed. The superelevation transition length (L_T) is the distance measured from the normal crown section to the full superelevation section. It is a function of the pavement width of rotation. Table 5-7 presents the minimum superelevation transition lengths for a 1 or 2 lane width of rotation.

The following procedure should be used to determine the distribution of the superelevation transition length between the tangent and curve:

Step 1: Determine the minimum superelevation transition length from Table 5-7 for a given design speed and width of rotation.

Step 2: For a 1-lane width of rotation, all curves should have full superelevation from the first 50-foot station occurring a minimum distance of 25 feet after the PC to the last 50-foot station occurring a minimum distance of 25 feet before the PT. For a 2-lane width of rotation, all curves should have full superelevation from the first 100-foot station occurring a minimum distance of 50 feet after the PC to the last 100-foot station occurring a minimum distance of 50 feet before the PT.

Step 3: Locate the beginning of the entering transition. This will be a distance equal to the superelevation transition length (Step 1) in advance of the station determined in Step 2. The end of the exiting transition will be a distance equal to the transition length (Step 1) beyond the last fully superelevated station determined in Step 2.

Example 3 illustrates the distribution of transition length on a simple horizontal curve.

Design Speed (mph)	Width of Rotation	
	L_T (1 - lane each way)	L_T (2 - lanes each way)
$V \leq 55$	200 ft	300 ft
$V > 55$	250 ft	400 ft

Notes:
1. A 1-lane width of rotation applies where 2 lanes are rotated about the centerline.
2. A 2-lane width of rotation applies where 4 lanes are rotated about the centerline or where 3 lanes are rotated about one of the edges of the interior lane or construction centerline.
3. For a 3-lane width of rotation: L_T (3 lanes) = 2.0 x L_T (1-lane).
4. For a 4-lane width of rotation: L_T (4 lanes) = 2.5 x L_T (1-lane).

MINIMUM SUPERELEVATION TRANSITION LENGTH (L_T)
(Rural Highways and High-Speed Urban Highways)

Table 5-7

* * * * * * * * * *

Example 3

Given: Figure 5-4 illustrates the horizontal curve and stationing.
Design Speed = 50 mph.
2-lane roadway (rotated about the centerline).

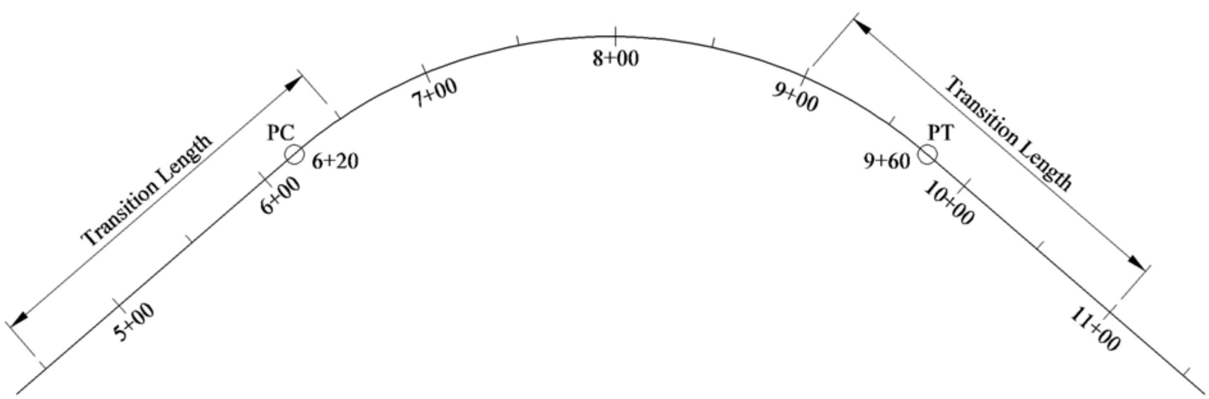
Problem: Determine the superelevation transition length and the beginning and ending stations.

Solution: From Table 5-7, the minimum superelevation transition length is 200 ft.

Entering transition: From Figure 5-4, the first full 50-ft station at least 25 ft beyond the PC is station 6+50 (full superelevation).

Exiting transition: From Figure 5-4, the last fully superelevated section will be at station 9+00.

Beginning and ending transitions: Measure 200 ft back from station 6+50 to station 4+50 (begin superelevation transition) and measure 200 ft ahead from station 9+00 to station 11+00 (end superelevation transition).



Data: V = 50 mph
L_T = 200 ft
Rotate about centerline

DISTRIBUTION OF SUPERELEVATION TRANSITION LENGTH
(Example 3)

Figure 5-4

* * * * * * * * * *

Reverse Curves

For closely spaced reverse curves, it may not be practical to achieve a normal crown section between the curves. A plane section continuously rotating about its axis (e.g., centerline) can be maintained between the two curves, if they are close enough together. However, the designer should adhere to the superelevation development criteria for each individual curve. The following will apply to reverse curves:

1. The designer should not attempt to achieve a normal crown section between reverse curves unless the normal section can be maintained for at least 150 feet ($45 \leq V \leq 55$) or 200 feet ($V > 55$ mph) and the superelevation transition requirements can be met for both curves.

2. When a normal crown section is not provided and 1-lane is being rotated, the minimum recommended distance between the PT (first curve) and PC (second curve) is 200 feet. The pavement will remain in a plane throughout the tangent section continuously rotating about its axis.

3. When a normal crown section is not provided and two lanes are being rotated, the minimum recommended tangent distance is 300 feet. The pavement will remain in a plane throughout the tangent section.

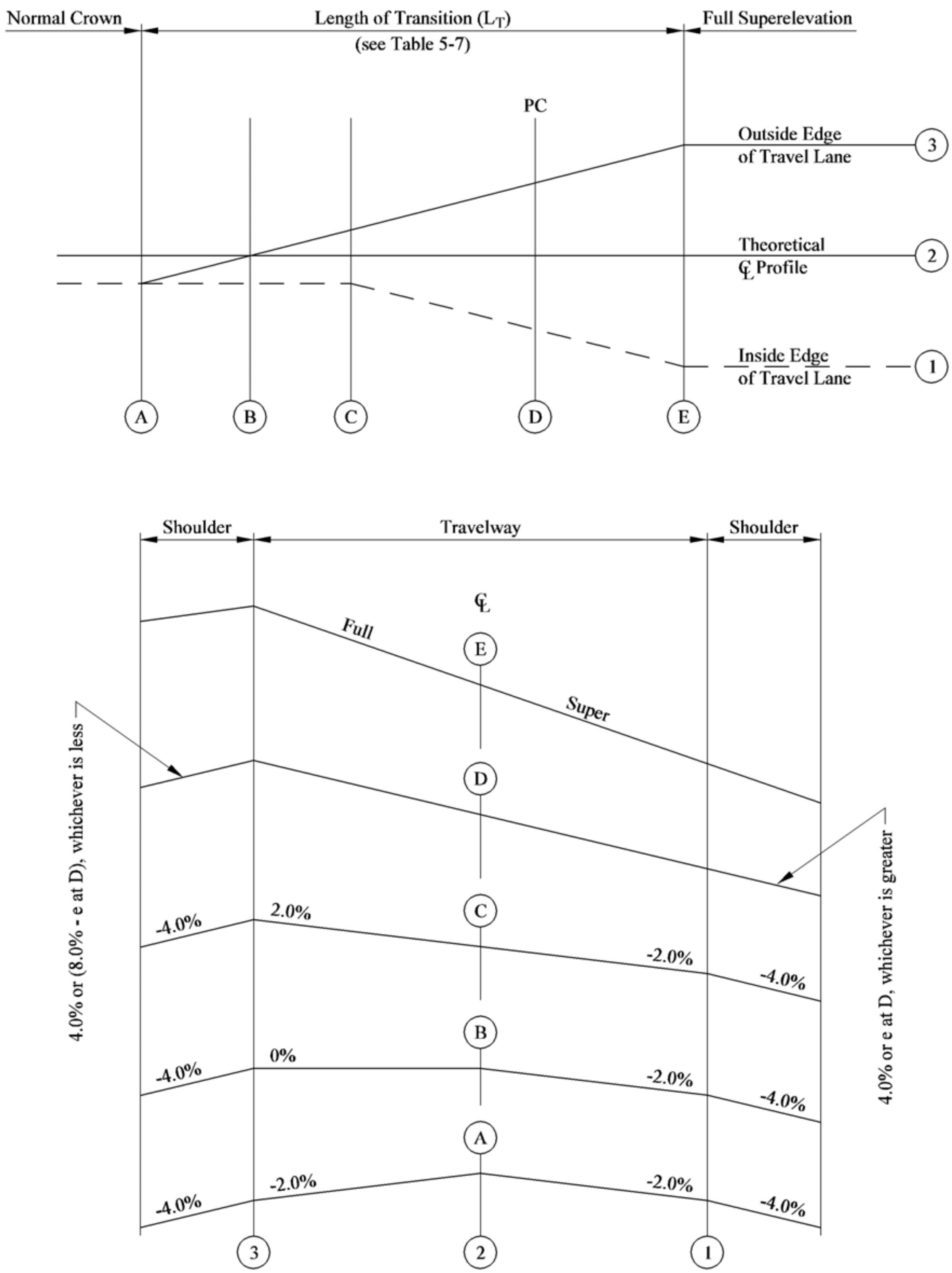
Axis of Rotation

1. ***Undivided Highways***. On 2-lane highways and undivided multilane highways, the axis of rotation will be the centerline of the roadway. Rotation about the centerline profile is illustrated in Figure 5-5. On a 2-lane roadway with an auxiliary lane, such as a climbing lane, the axis of rotation will be the centerline of the two through lanes.

2. ***Divided Highways***. Divided highways with medians require special consideration. Table 5-8 presents the recommended axis of rotation for divided highways based on median widths. The designer should select an axis based on the specific site conditions at the curve.

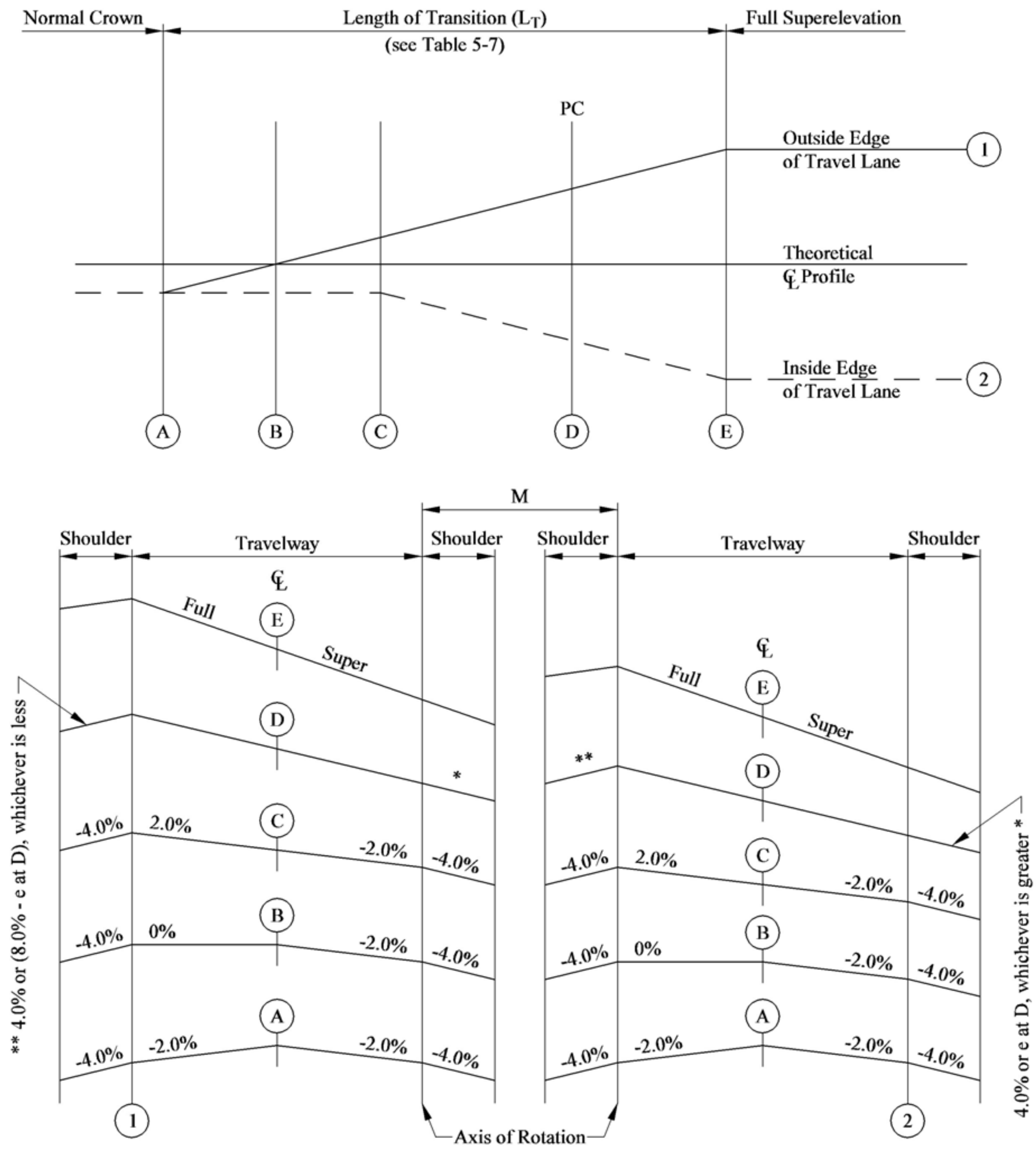
Shoulder Superelevation

The algebraic difference between the travel lane slope and the shoulder slope ("rollover") should not exceed 8.0%. Details of shoulder superelevation are illustrated for various points along the superelevation transition length in Figures 5-5 and 5-6.



ROTATION ABOUT CENTERLINE
(Undivided Highways)

Figure 5-5



Notes:

1. For distribution of transition length, see Section 5-2.05.
2. "Rollover" between travel lane and shoulder should not exceed 8.0%.
3. For paved medians less than 20 ft, the shoulder slope rates and median edge profiles may need to be adjusted for drainage purposes. This adjustment should be achieved in the transition length.

ROTATION ABOUT MEDIAN EDGE OF INSIDE TRAVEL LANE
(Divided Highway – M ≤ 40 ft)

Figure 5-6

Median Width	Axis of Rotation	Figure
M ≤ 40 ft	median edge of inside travel lane	5-6
M > 40 ft	separately about centerline of each roadway	5-5

Note: For treatment of superelevated curves with median barriers, see Chapter Ten "Roadside Safety."

RECOMMENDED AXIS OF ROTATION
(Divided Highways)

Table 5-8

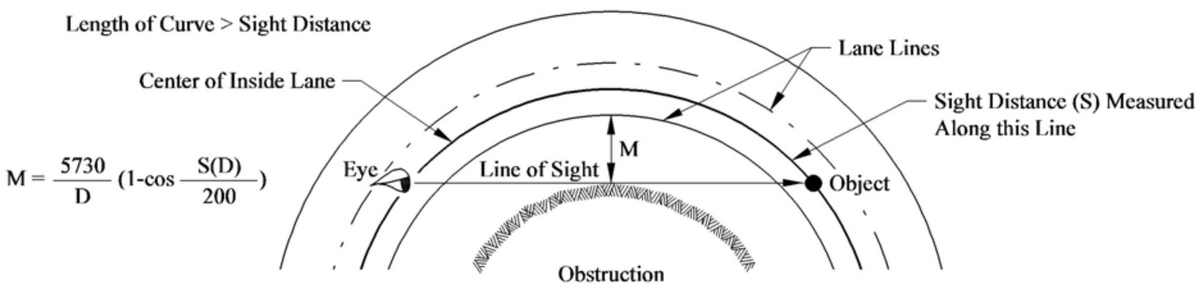
5-2.06 Horizontal Sight Distance

The designer should evaluate the impact on sight distance of obstructions which are on the inside of horizontal curves. These include walls, cut slopes, wooded areas, buildings and sometimes guardrail.

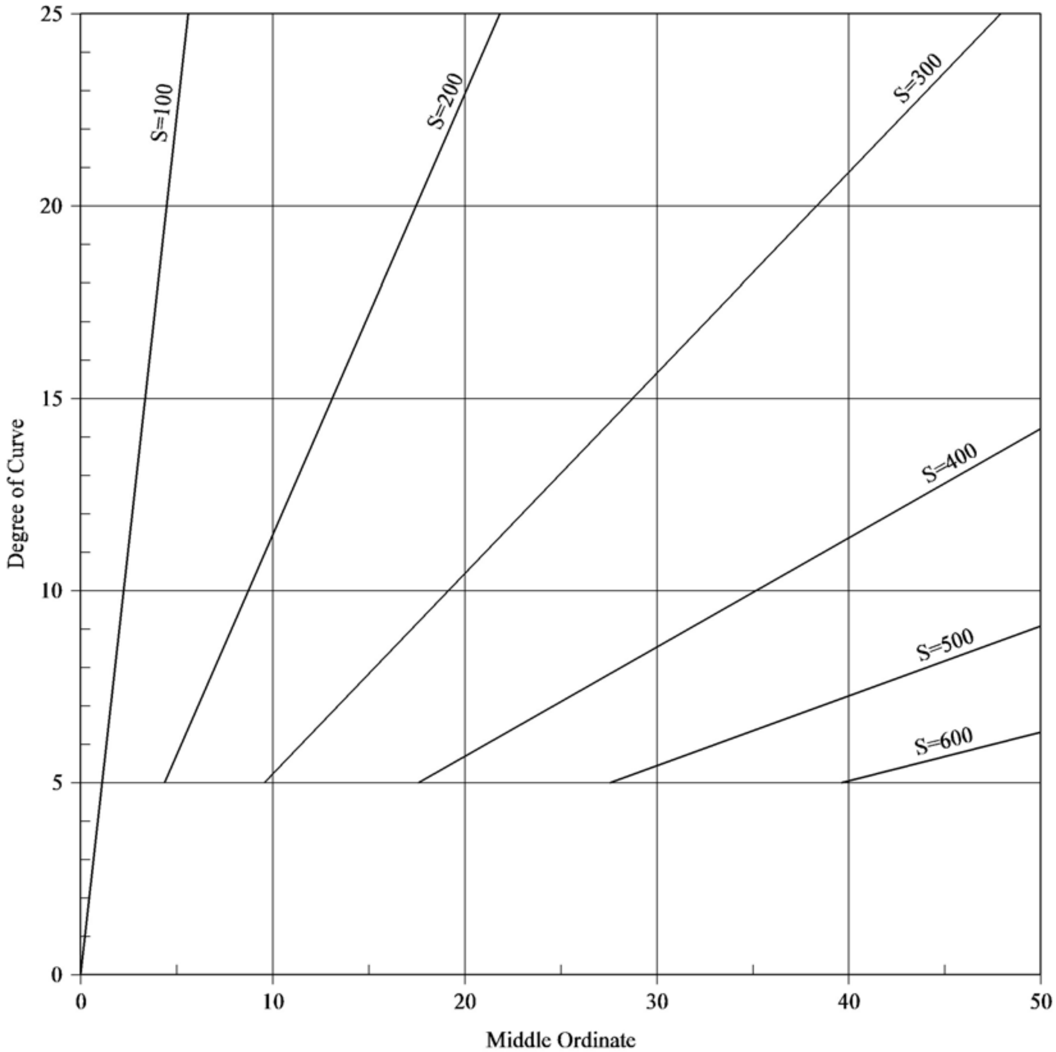
Stopping Sight Distance

The designer should provide an adequate "middle ordinate" (M) between the center of the inside travel lane and the sight obstruction. Figures 5-7a, 5-7b and 5-8 provide the criteria for various combinations of curve radius and sight distance. The stopping sight distances (SSD) in both figures are based on the level criteria. To determine the middle ordinate for the grade-adjusted SSD, the equation in the figure may be used directly to calculate the value.

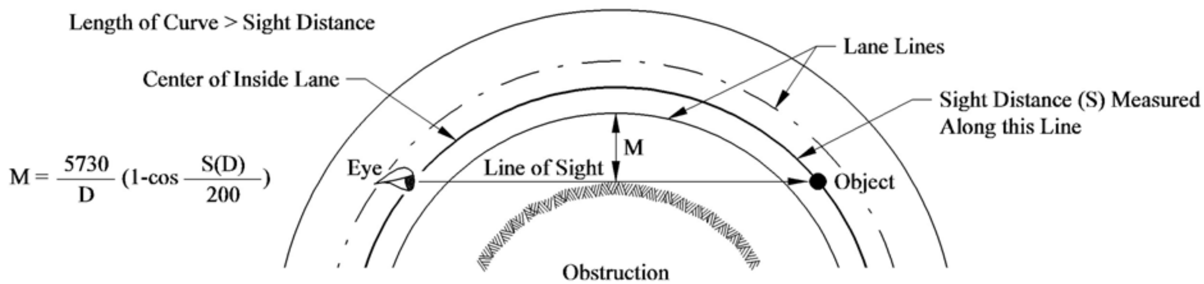
The M values from Figures 5-7a, 5-7b and 5-8 apply between the PC and PT. This area should be free of all sight obstructions. In addition, some transition is needed on either side of the curve. This is illustrated in Figure 5-9. The designer should use the following procedure:



Where: M = Middle Ordinate, distance from the line of measure (center of inside lane) to the obstruction, ft
D = Degree of Curve
S = Sight Distance, ft



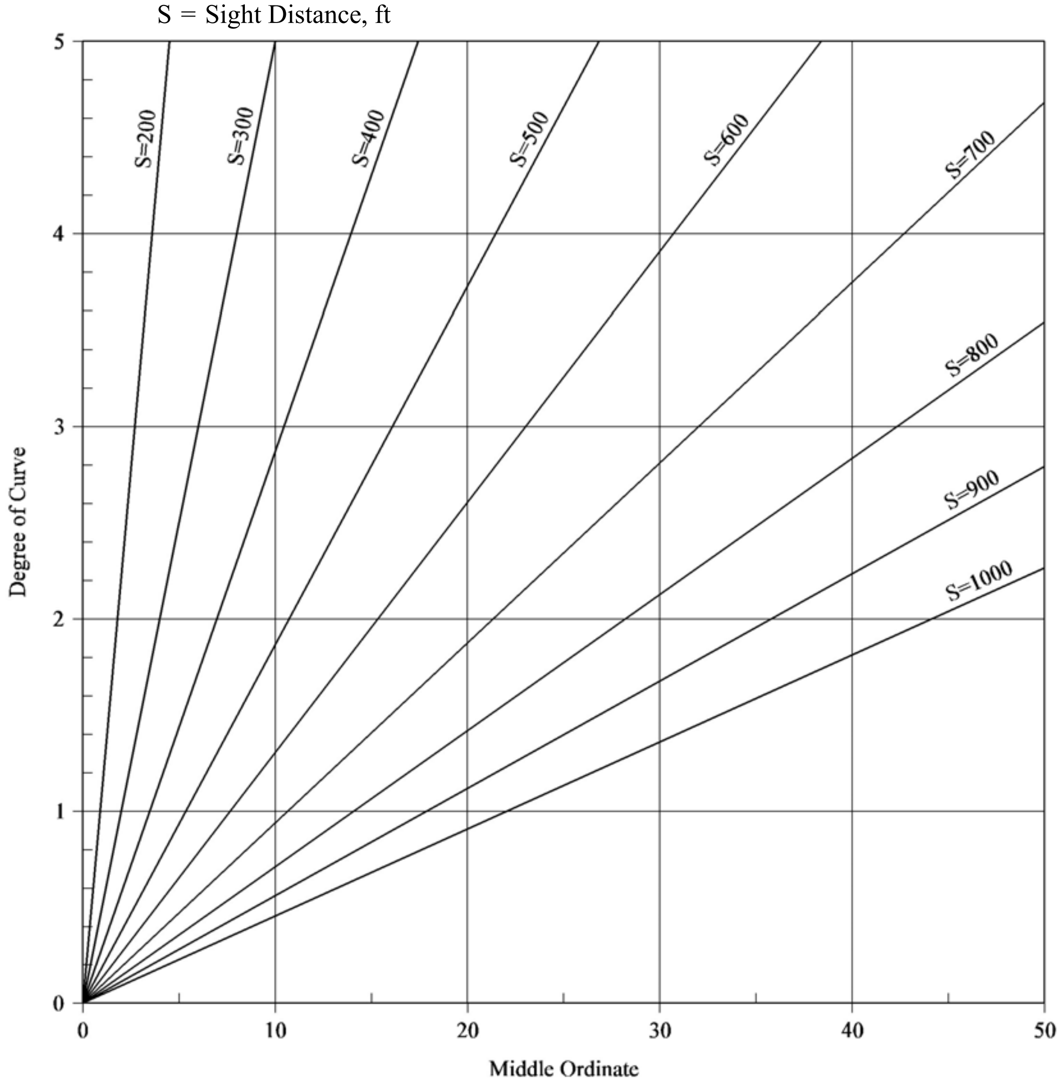
STOPPING SIGHT DISTANCE AT HORIZONTAL CURVES
(Range of Lower Values – D > 5°)
Figure 5-7a



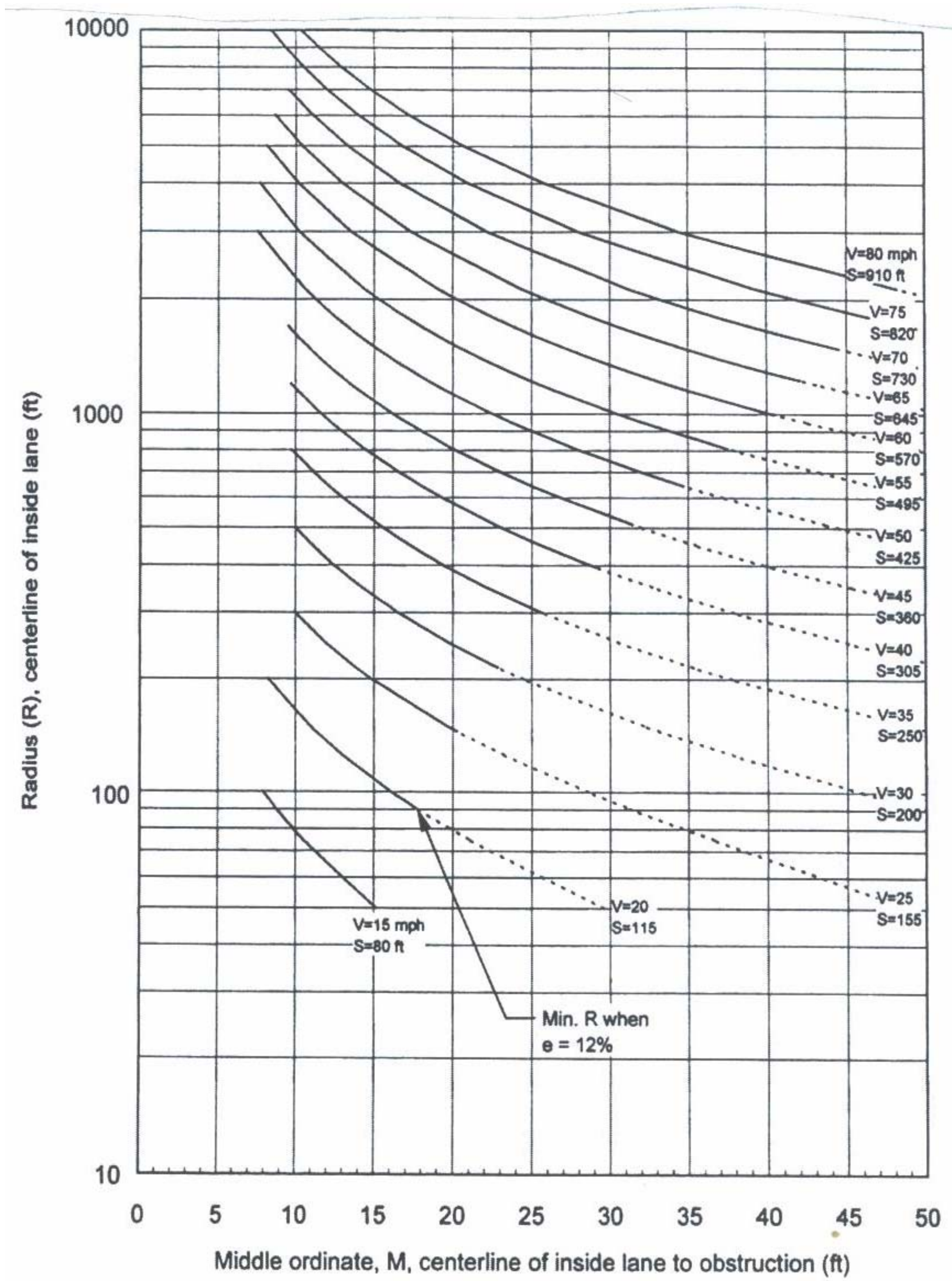
Where: M = Middle Ordinate, distance from the line of measure (center of inside lane) to the obstruction, ft

D = Degree of Curve

S = Sight Distance, ft



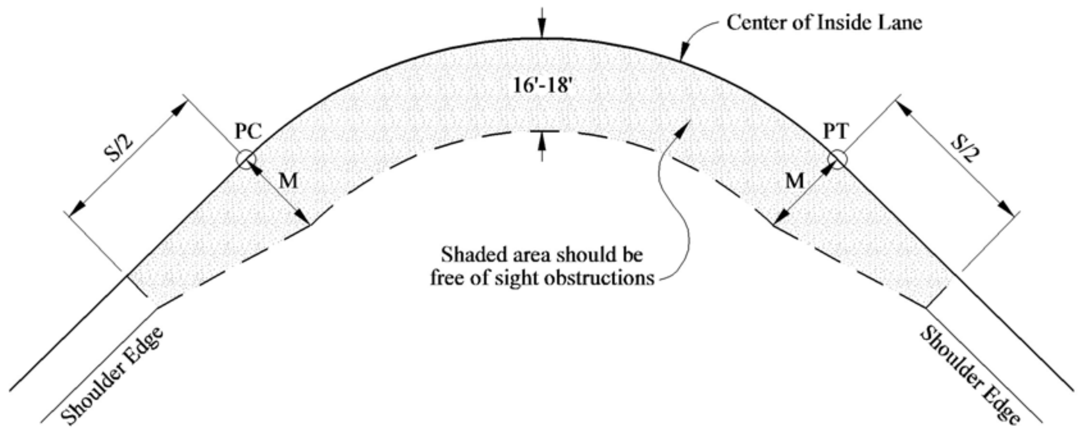
STOPPING SIGHT DISTANCE AT HORIZONTAL CURVES
(Range of Upper Values – D < 5°)
Figure 5-7b



$$M = R\left[\left(1 - \cos\frac{28.65S}{R}\right)\right]$$

STOPPING SIGHT DISTANCE (RADIUS) ON HORIZONTAL CURVES

Figure 5-8



Example

Given: Urban Freeway
Design speed = 60 mph
Degree of curve = 2° 15' Radius = 2546 ft
Grade = 3% downgrade
SSD = 570' (without grade adjustment)
SSD = 600' (with grade adjustment)

Problem: Determine the stopping sight distance clearance requirements for the horizontal curve for both SSD values.

Solution: From Figure 5-7b, the middle ordinate distance applied between the PC and PT of the curve is 18 ft for SSD = 600' and 16 ft for SSD = 570'. The application of the clearance requirements throughout the entire curve, including the entering and exiting transition, is illustrated above.

OR

From Figure 5-8, using V=60 mph or SSD=570 ft yields an M value of 17 ft.

MINIMUM CLEARANCE REQUIREMENTS FOR HORIZONTAL SIGHT DISTANCE

Figure 5-9

* * * * * * * * * *

Step 1: Locate the point which is on the outside edge of shoulder and a distance of SSD/2 before the PC.

Step 2: Locate the point which is a distance M measured laterally from the center of the inside travel lane at the PC.

Step 3: Connect the two points located in Steps 1 and 2. The area between this line and the roadway should be clear of all obstructions.

Step 4: A symmetrical application of Steps 1-3 should be used beyond the PT.

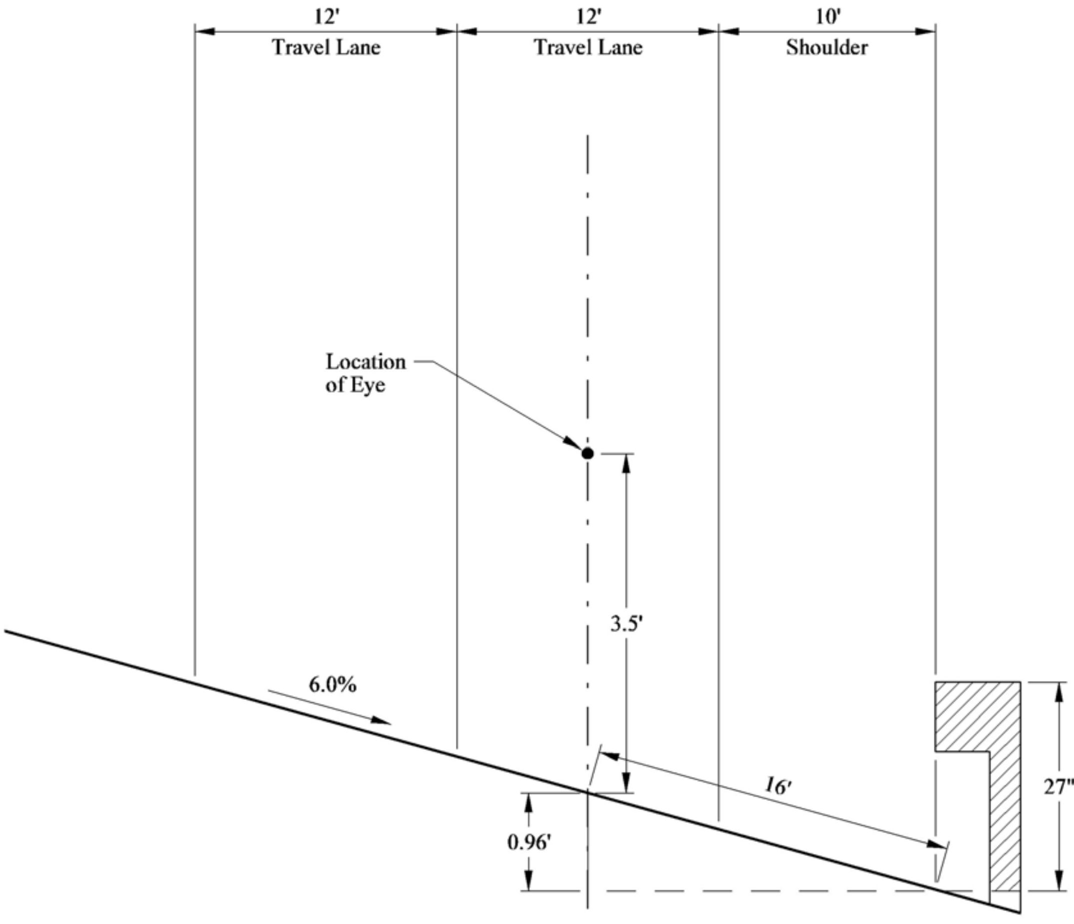
For application, the height of eye is 3.5 feet and the height of object is 2 feet. The line-of-sight intercept with the obstruction is at the midpoint of the sight line and 2.75 feet above the center of the inside lane. The designer should consider the height advantage afforded by a superelevated curve. As illustrated in Figure 5-10, this elevates the center of the inside travel lane by as much as 1 foot when compared to the edge of the inside shoulder. This will greatly reduce the probability that guardrail will present a sight obstruction on the inside of a horizontal curve.

Decision Sight Distance

Table 4-3 provides values for decision sight distance. At a horizontal curve, for example, decision sight distance may be appropriate for a traffic signal located just beyond a curve on a rural arterial. Where decision sight distance is used, the designer should use the equation in Figure 5-7a to calculate the clearance requirements.

Passing Sight Distance

On high-volume, 2-lane roadways, it may occasionally be warranted to provide passing sight distance around horizontal curves to achieve a higher PSD percentage on the highway. Table 4-4 provides values for passing sight distance. These values yield large numbers for the required clearance, and their application should be limited to flat curves where the right-of-way impacts will be a minimum. Where passing sight distance is used, the designer should use the equation to calculate the clearance requirements.



ELEVATION DIFFERENTIAL ON SUPERELEVATED CURVES

Figure 5-10

5-3 LOW-SPEED URBAN STREETS

The operating conditions on low-speed urban streets (design speed of 45 mph or less) are significantly different from those on rural highways and high-speed urban highways. In addition, urban areas present different physical constraints which should be considered.

5-3.01 Horizontal Curves

Criteria and definitions presented in Sections 5-1 and 5-2 will apply to low-speed urban streets. However, the following additional guidance is offered specifically for these facilities:

1. ***Types of Curvature***. The simple curve is the most common type of horizontal curve used on low-speed urban streets. Compound curves may be warranted where a physical obstruction prevents the use of a simple curve. They will rarely be used for transition purposes.

2. ***Maximum Degree of Curve***. Table 5-9 provides the maximum degree of curve for each design speed on low-speed urban streets. The designer should provide flatter horizontal curves where possible.

3. ***Travelway Widening***. Travelway widening on curves is rarely warranted on low-speed urban streets.

5-3.02 Length of Curves

Calculated versus Minimum

The criteria for "Collector and Local Roads" in Table 5-4 will also apply to low-speed urban streets. An exception to this is the criteria for sharpest deflection with no curve, which is discussed in the following paragraph.

Sharpest Deflection with No Curve

On low-speed urban streets, a deflection angle of less than 1 degree without a horizontal curve may not have a significant effect on driver response or aesthetics. Therefore, the designer should consider leaving in the angle point when the deflection is less than about 1 degree.

Design Speed (mph)	Minimum Radius
20	80 ft
25	145 ft
30	230 ft
35	350 ft
40	500 ft

Note: e_{max} = 4.0%

MINIMUM RADIUS
(Low-Speed Urban Streets)

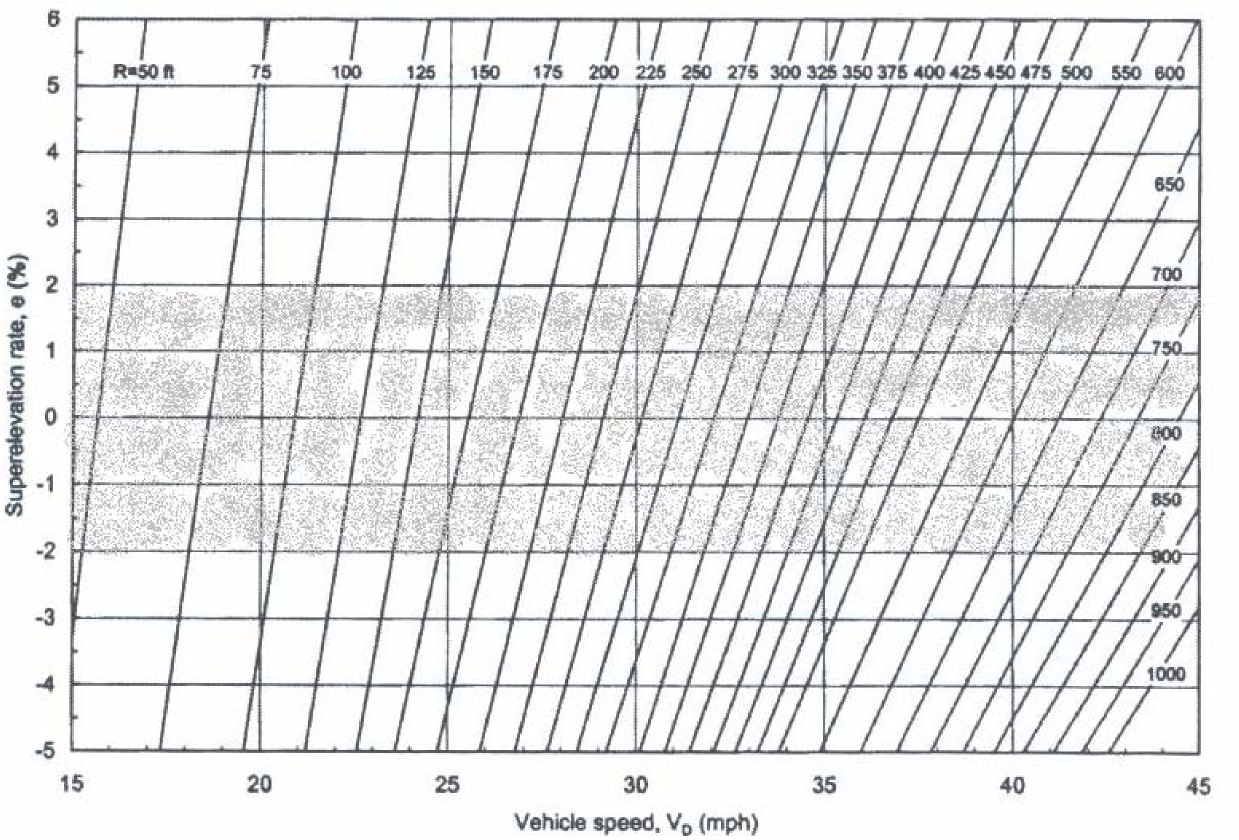
Table 5-9

5-3.03 Superelevation Development

Superelevation Rate

The Department has adopted e_{max} = 4.0% for the design of low-speed urban streets. Figure 5-11 provides the criteria for superelevation rates for urban streets based on design speed and radius

The designer should exercise special care when the "theoretical" superelevation rate is between -2.0% and +2.0% (typical cross slope). In this range, the curve should be superelevated at the rate of the cross slope (2.0% typical) toward the inside of the curve. This is referred to as remove crown (RC). This range is highlighted on Figure 5-11. Table 5-10 provides the corresponding degree of curve for a normal crown section and a remove crown section for a cross slope of 2.0%. Examples 4, 5 and 6 illustrate the use of Figure 5-11 and Table 5-10 to determine the proper superelevation rate.



Notes:

1. e_{max} = 4.0%
2. For curves within the shaded area, superelevate the entire traveled way at the rate of cross slope (2.0%) toward the inside of the curve.
3. D = Degree of Curve

RATE OF SUPERELEVATION
(Low-Speed Urban Streets)

Figure 5-11

Design Speed (mph)	**Radius**		
	Normal Crown	***Remove Crown****	***See Figure 5-11***
20	R > 95 ft	95 ft ≥ R ≥ 85 ft	R < 85 ft
25	R > 180	180 ≥ R ≥ 155	R < 155
30	R > 300	300 ≥ R ≥ 250	R < 250
35	R > 465	465 ≥ R ≥ 375	R < 375
40	R > 680	680 ≥ R ≥ 535	R < 535

* *The flatter curve is based on a theoretical superelevation rate of -2.0%. The sharper curve is based on a theoretical superelevation rate of +2.0%.*

DEGREE OF CURVE FOR NORMAL CROWN SECTION AND REMOVE CROWN SECTION (Low-Speed Urban Streets)

Table 5-10

* * * * * * * * * *

<u>Example 4</u>

Given: Design speed = 30 mph
Radius = 347 ft
Cross slope (on tangent) = 2.0%

Problem: Determine the superelevation rate.

Solution: Table 5-10 indicates that a normal crown section should be used.

<u>Example 5</u>

Given: Design speed = 35 mph
Radius = 425 ft

Problem: Determine the superelevation rate.

Solution: From Table 5-10, a remove crown section applies. The pavement should be superelevated at a rate of 2.0% across the entire pavement.

Example 6

Given: Design speed = 40 mph
Radius = 500 ft

Problem: Determine the superelevation rate.

Solution: Table 5-10 directs the designer to Figure 5-11 to determine the superelevation rate. Figure 5-11 yields a required superelevation rate of +3.0%. Therefore, the entire pavement should be transitioned to this rate.

* * * * * * * * * *

Superelevation Transition Length

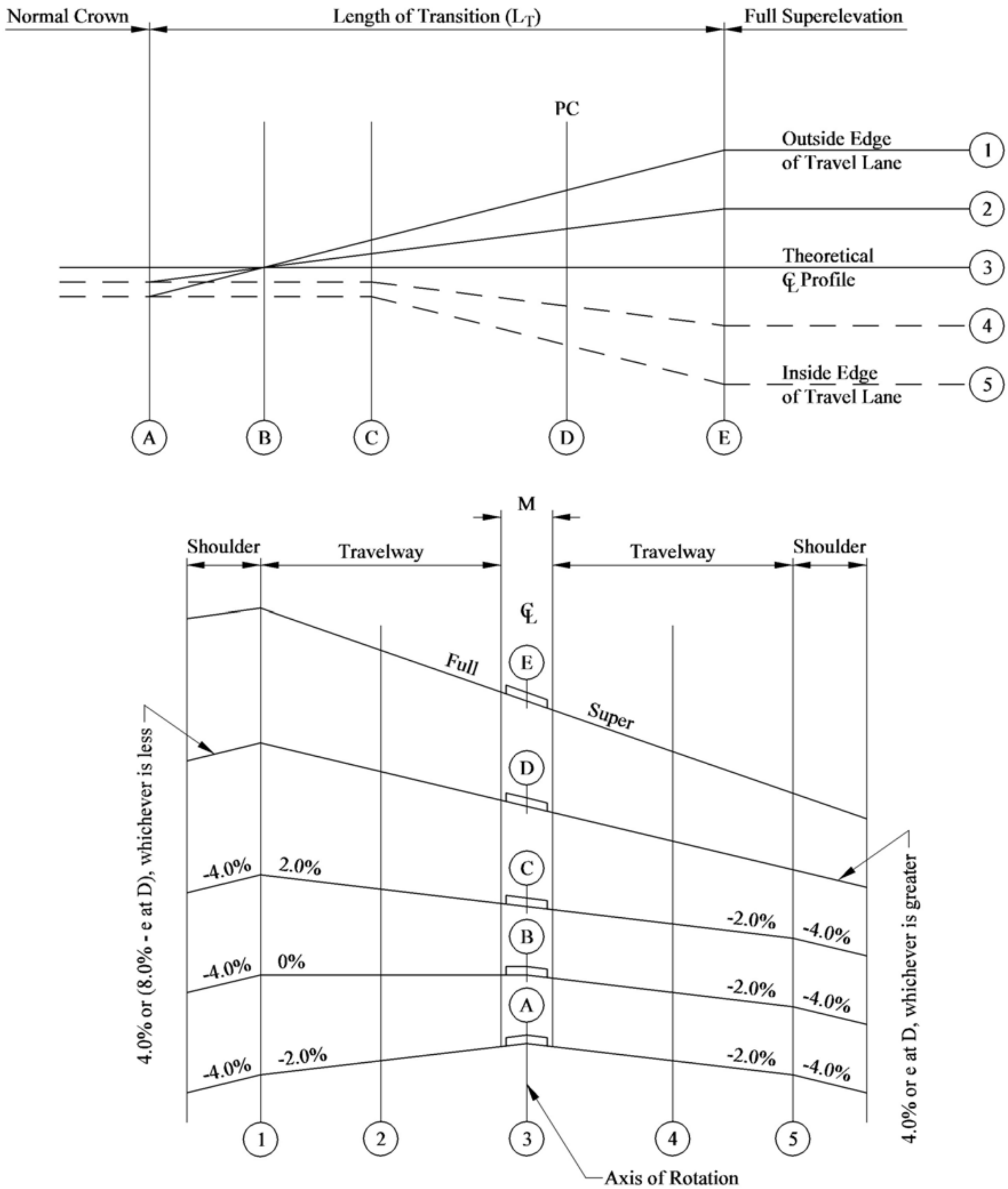
For low-speed urban streets, the minimum superelevation transition length for a 1-lane width of pavement rotation is 125 feet. For a 2-lane width of rotation, the transition length is 200 feet. The distribution of transition length on low-speed urban streets should follow the same procedure as discussed in Section 5-2.05.

Reverse Curves

Reverse curves may be used in urban areas. The designer should not attempt to achieve a normal crown section between curves unless the normal crown section can be maintained for at least 100 feet. See Section 5-2.05 for more information on superelevation transition on reverse curves.

Axis of Rotation

The criteria in Section 5-2.05 also apply to low-speed urban streets. However, on divided urban streets with median widths less than 15 feet, the axis of rotation will be the centerline. This is illustrated in Figure 5-12. Additionally, on a curbed street, it may occasionally be preferable to rotate about the outside or inside edge of travel lane because of drainage, right-of-way or other considerations.



Notes:

1. For distribution of transition length, see Section 5-2.05.
2. "Rollover" between travel lane and shoulder should not exceed 8.0%.

ROTATION ABOUT CENTERLINE
(Divided Highway M < 15 ft)

Figure 5-12

Shoulder Superelevation

The criteria in Section 5-2.05 also apply to low-speed urban streets. The designer should note, however, that 4 feet is the minimum shoulder width which should be sloped away from the travel lane on the outside of a superelevated curve. For lesser shoulder widths, or "offsets", the outside shoulder should be sloped in the same direction as the travel lane.

5-3.04 Horizontal Sight Distance

The criteria presented in Section 5-2.06 also apply to horizontal sight distance on low-speed urban streets.

CHAPTER SIX
CROSS SECTION ELEMENTS

Volume I

- Highway Design Guide - National Standards

December 2004

Chapter Six

TABLE OF CONTENTS

Page

Chapter Six

CROSS SECTION ELEMENTS

Chapter Seven, "Geometric Design Tables," provides design criteria for various cross section elements on new construction and reconstruction projects. Chapter Eleven, "Geometric Design of Existing Highways," provides design criteria for cross sections on 3R and 4R projects. This chapter will discuss the cross section elements and will provide additional guidance which should be considered in design.

6-1 ROADWAY SECTION

6-1.01 Travel Lanes

1. ***Widths***. Lane widths for the travelway vary between 10 and 12 feet depending on the functional classification, traffic volumes, rural/urban area and project scope of work. Chapters Seven and Eleven provide specific criteria.

2. ***Cross Slopes***. Travel lanes on tangent sections should be sloped sufficiently to ensure proper drainage of the pavement; this will normally be 2.0% for both concrete and bituminous pavements. An exception will be on multilane undivided highways with curbs and a shoulder width (or curb offset) less than 4 feet. On these facilities, the outside travel lane in each direction should be sloped at 3.0%.

6-1.02 Shoulders and Curb Offsets

1. ***General.*** Shoulders and curb offsets serve many functions including structural support, increased capacity and providing an area for emergency parking and a recovery area for vehicles.

2. ***Widths.*** Shoulder widths vary according to functional classification, traffic volumes, urban/rural location, curbed/uncurbed facilities and project scope of work. See Chapters Seven and Eleven. On uncurbed roads, shoulder width is measured form the edge of travel lane to the intersection of the shoulder slope and the side slope. On curbed streets,

the distance between the travel lane and curb must be at least 4 feet to be considered a shoulder. Distances less than 4 feet are considered "curb offsets."

3. ***Surface Type***. Shoulders should be paved in the following areas:

   a. all projects on the National Highway System;

   b. where the majority of shoulders in a corridor, or from logical termini to logical termini, are presently paved;

   c. all guardrail shoulders. Note: If a project is mostly guardrail shoulders requiring pavement, then all shoulders should be paved. Judgment must be exercised in these cases;

   d. on projects that are currently on designated bikeways;

   e. on projects that are within areas designated in the Bicycle/Pedestrian Plan. Exception: When a project occurs in a corridor that is in the Bicycle/Pedestrian Plan and the shoulders are all or mostly gravel, then gravel shoulders should be retained until a future project is initiated that would pave shoulders for the entire length of the corridor;

   f. in built-up areas that contain schools, residences, recreational facilities, etc.;

   g. paving of shoulders should also be considered in areas adjacent to side roads where there are relatively high-turning movements; and/or

   h. where the design year AADT is 4000 or greater.

   Projects that should have gravel shoulders are those that occur in corridors, or from logical termini to logical termini, where the majority of shoulders are presently gravel. Typically, the design year AADT will be less than 4000.

4. ***Cross Slopes***. The following will apply to cross slopes for shoulders and curb offsets:

   a. paved – 4.0%
   b. gravel – 6.0%
   c. curb offset – same as adjacent travel lane.

6-1.03 Auxiliary Lanes

Auxiliary lanes include left- and right-turn lanes, climbing lanes and continuous two-way left-turn lanes. Auxiliary lanes should be as wide as the through lane but not less than 10 feet. Specific criteria are provided in Chapters Seven and Eleven. See Table 8-4 for transition lengths.

6-1.04 On-Street Parking

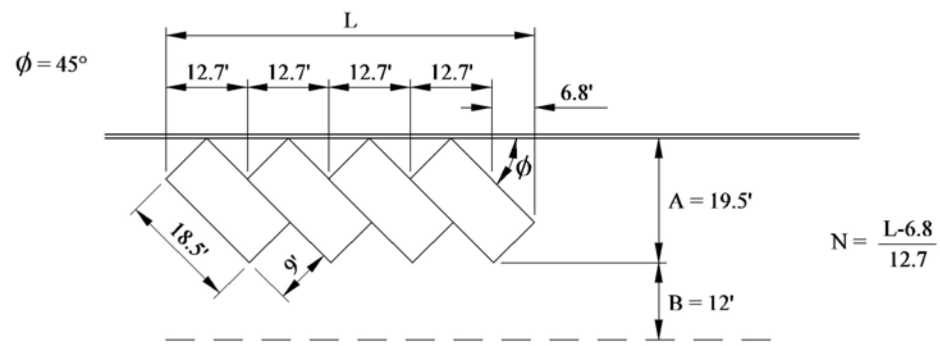
Parallel Parking

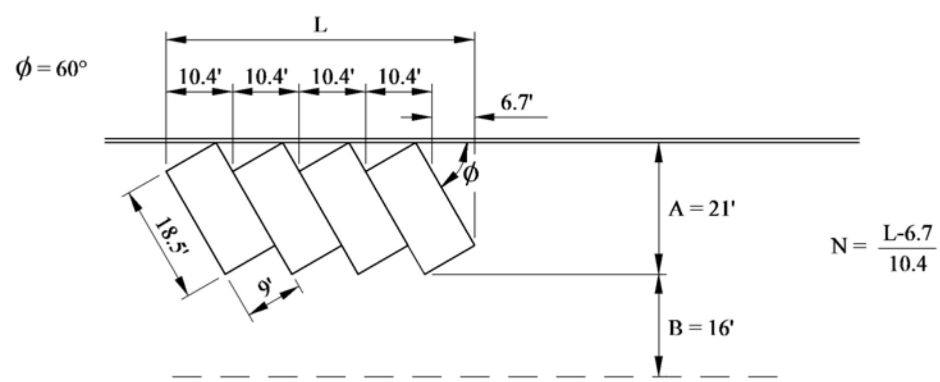
When on-street parking is appropriate, the designer should use parallel parking. The width of a parking lane varies from 7 to 12 feet depending on the functional classification and project scope of work. The length varies from 22 to 26 feet with the end spaces being 20 feet long. See Chapters Seven and Eleven for specific criteria.

Angle Parking

Where angle parking currently exists, it is acceptable to retain the angle parking in the proposed project design. The designer should consider converting the angle parking to a parallel configuration, if practical. Figure 6-1 provides the width and length criteria for parking stalls for 45° and 60° angle parking on a through street. The figure also indicates the number of stalls which can be provided for each angle for a given curb length.

The designer should especially consider the backing maneuver required by angle parking. As indicated in Figure 6-1, the parked car will require a certain distance "B" to back out of its stall. Whether or not this is a safe maneuver will depend upon the number of lanes in each direction, lane widths, operating speeds, traffic volumes during peak hours, the parking demand and turnover rate of parked vehicles.





Key:

L = given curb length within parking spaces

N = number of parking spaces over distance L

B = minimum clear distance needed for a parked vehicle to back out of stall while just clearing adjacent parked vehicles

A = required distance face of curb and back of stall, assuming that bumper of parked car does not extend beyond curb face. In restricted locations, it can be assumed that the car will move forward until its tire contacts the curb. In these cases, the "A" distances in the figure may be reduced as follows:

Angle of Parking	Reduction in "A"
45°	1.8'
60°	2.2'

ANGLE PARKING

Figure 6-1

Parking Restrictions

The following restrictions will typically apply to on-street parking:

1. parking should be prohibited within 20 feet of any crosswalk;

2. parking should be prohibited within 25 feet of the terminus of the corner radius along the curb line at street intersections;

3. parking should be prohibited in front of all driveway entrances and 10 feet to either side;

4. parking should be prohibited within 15 feet of any hydrant; and

5. parking should be prohibited within 50 feet of the nearest rail of a railroad/highway crossing.

6-1.05 Off-Street Parking

A proposed highway project may incorporate some form of off-street parking. Typical applications may include:

1. providing off-street parking to replace on-street parking which will be removed as part of a proposed project;

2. the construction of a park-and-ride lot for commuters; or

3. the construction of a new rest area or improvement to an existing rest area.

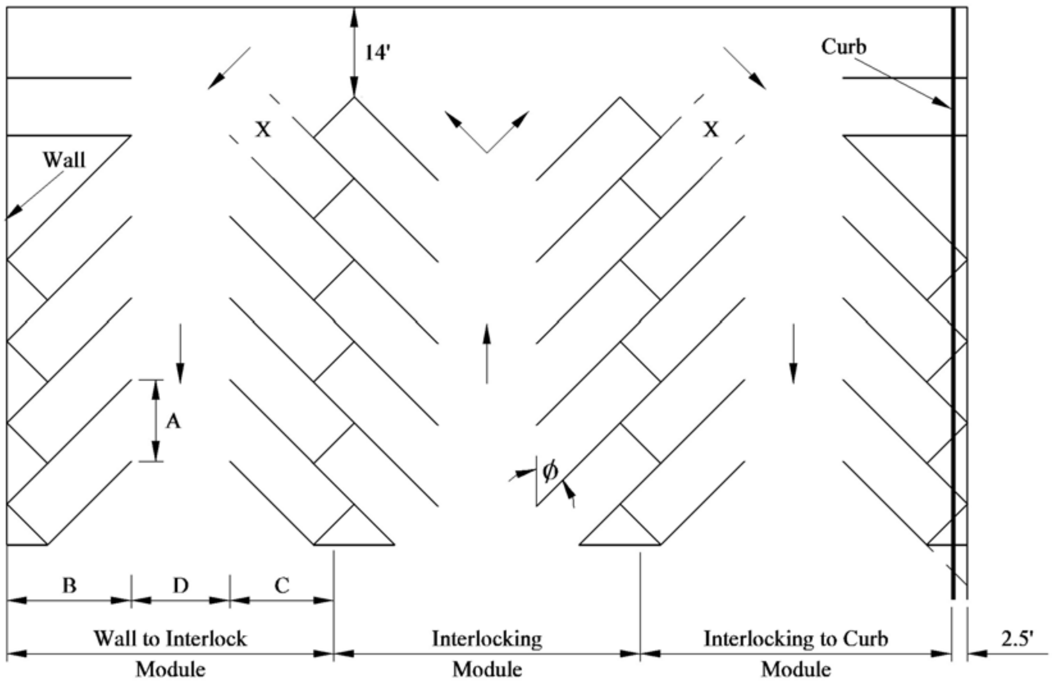
Figure 6-2 provides the design details for off-street parking. The figure is based on the following:

1. accommodating exclusively large passenger vehicles;

2. accommodating high parking turnover (e.g., retail establishments, fast-food restaurants, banks); and

3. providing 9-foot wide stalls.

The design in Figure 6-2 is the most generous design recommended by ITE in its publication *Traffic Engineering Handbook*. Where the dimensions in the figure are not practical, see the ITE publication for other criteria for the design of off-street parking.



	A	*B*	*C*	*D*		
Basic Stall Width (ft)	**Stall Width Parallel to Aisle (ft)**	**Stall Depth to Wall (ft)**	**Stall Depth to Interlock (ft)**	**Aisle Width (ft)**	**Modules**	
					Wall-to-Wall (ft)	***Interlock-to-Interlock (ft)***
2-Way Aisle x 90° 9.0	9.0	17.5	17.5	26	61	61
2-Way Aisle x 60° 9.0	10.4	17.8	16.5	26	61.6	59
1-Way Aisle x 75° 9.0	9.3	18.5	17.5	22	59	57
1-Way Aisle x 60° 9.0	10.4	17.8	16.5	18	53.6	51
1-Way Aisle x 45° 9.0	12.7	16.5	14.5	15	48	44

Notes: These dimensions are subject to slight reductions by local agencies under high cost conditions (such as garages) or slight increases in areas subject to special needs (such as extensive snowfall).

X = Stall not accessible in certain layouts

* May also apply to boundary curb where bumper overhang is allowed.
** To vehicle corner

CRITERIA FOR OFF-STREET PARKING LOTS

Figure 6-2

6-1.06 Curbs

General Usage

Curbs are often used on urban streets, and occasionally on rural highways, to control drainage, delineate the pavement edge, channelize vehicular movements, provide separation between vehicles and pedestrians, and present an attractive appearance. The Department has adopted the following general criteria for where curbs should be used:

1. Vertical Curbs. These should be used adjacent to sidewalks.

2. Sloping Curbs. These should be used around islands and other curb locations where sidewalks are not present. A low profile sloping curb (4" max height) should be used in high speed areas (greater than 45 mph).

3. Existing Curbs. Normally, these are replaced in kind.

On streets maintained by the municipality, the decision will be coordinated with the local government.

Types (By Material)

The Department uses bituminous and granite curbs as follows:

1. ***Type 3 Bituminous***. Bituminous curbs are typically used in rural areas with occasional box sections, on low-volume residential box sections, on low-volume residential streets or roadways and under guardrail on the low side of superelevated sections. Bituminous curb is referred to as Type 3 curb and can be designated by one of 3 mold shapes.

2. ***Granite***. Granite curbs are typically used in business districts and downtown areas where on-street parking and/or high through and turning volumes are prevalent. Type 1 is a vertical granite curb and Type 5 is a slope granite curb.

Types (By Shape)

The two general types of curbs are vertical curbs and sloping curbs. Each type has distinct physical features and usage. These are summarized as follows:

1. ***Vertical Curbs***. Vertical curbs are typically used in urban areas. They should always be used where sidewalks are located adjacent to the roadway. The two vertical curbs used by the Department are designated Type 1, Type 3 (mold 1). Type 1 is a vertical face granite curbing with a 7-inch reveal and Type 3 (mold 1) is a bituminous molded curb with a 6½-inch reveal. Where a vertical curb is used in a rural area, the Type 3 bituminous curb will normally be used. In addition, vertical curbs should not be used where design speeds exceed 45 mph except:

   a. where the location is predominantly urban or rapidly developing urban (up to and including 50 mph design speed); and

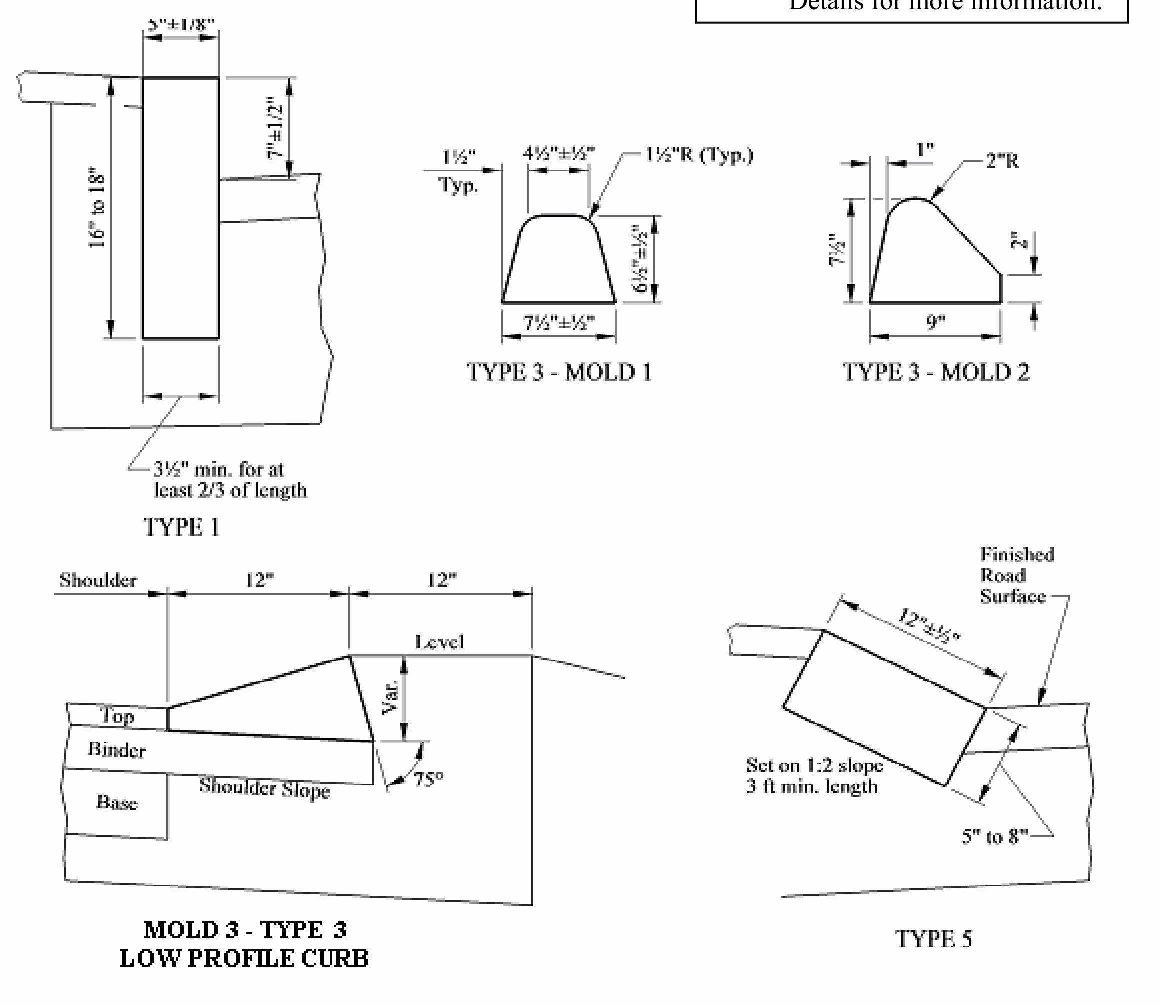
   b. for special drainage considerations.

2. ***Sloping Curbs***. In general, the use of curbs is discouraged on high speed roadways, however when curbs are deemed necessary a low profile sloping curb shall be used. Sloping curbs should be used where curbs are warranted and vertical curbs are not recommended because of design speed restrictions. Sloping curbs allow moving vehicles to cross up and over the curb in emergency conditions. The three sloping curbs used by the Department are designated Type 3 (mold 2) Type 3 (mold 3) and Type 5. Type 3 (mold 2) is a bituminous curb with a sloped face and a 7½-inch reveal. Type 3 (mold 3) is a bituminous curb with a flatter sloped face and a 4 inch revel. Type 3 (mold 3) is referred to as a low profile curb and should be used in areas where design speeds exceed 45 mph. Type 5 is a granite edge curb with a sloped face on a 2:1 slope. Type 5 curbing is typically used at the edges of channelized islands and at raised medians. The low profile curb (Type 3 mold 3) should be used on high speed roadways (greater than 45 mph design speed).

Figure 6-3 presents a summary of curb types available in Maine based on the shape and material. See the Departments *Standard Details* for more information. Where a curb and barrier are used together, the face of the curb should be in line with the face of the barrier and the max curb height shall be 4”. Figure 6-11 provides the detail for the curb/barrier design.

Curb Type	Shape	Material
Type 1	Vertical	Granite
Type 3 (mold 1)	Vertical	Bituminous
Type 3 (mold 2)	Sloping	Bituminous
Type 3 (mold 3)	Sloping	Bituminous
Type 5	Sloping	Granite

Note: See Department's Standard Details for more information.



CURB TYPES
Figure 6-3

6-1.07 Sidewalks

Warrants/Funding

Sidewalks are considered an integral part of the urban environment for pedestrian movement. In addition, they may have sufficient value in some rural areas and in the vicinity of schools and businesses to warrant consideration. The following will apply to sidewalk warrants:

1. ***Currently Exist***. Where sidewalks currently exist, they will be replaced in kind and improved to meet the Department's existing criteria if affected by construction. In this case, the funding for the sidewalk work will be the same as the roadway work whether the sidewalk is fully reconstructed or only receives a hot bituminous overlay. When, as a part of a project, an existing sidewalk is reconstructed but the municipality wishes to use a surface other than that which existed previously, it would then be the municipality's responsibility to pay all of the non-Federal share of the additional cost for the requested surface. As an example, a municipality requests that, rather than using superpave hot mix, the project include a brick sidewalk; then, the non-Federal share of the additional cost of the brick surface must be paid for by the town or city.

   An exception to the above applies if both the Department and Town/City agree in writing to eliminate an existing sidewalk.

2. ***Currently Do Not Exist***. Where sidewalks do not currently exist, the need for sidewalks will be determined on a case-by-case basis. When local municipalities request a new sidewalk as part of a roadway project, they are responsible for 100% of the non-Federal share of the construction costs of the sidewalk. When the project is not Federally funded, it is the municipality's responsibility to pay 50% of the State's share of the cost. The cost is intended to include gravel, pavement and any additional construction features made necessary by widening for the sidewalk such as retaining walls or barriers. It does not include right-of-way.

   When a municipality or town requests that sidewalks be constructed as part of a project in an area where there are no existing sidewalks after a project has been advertised, the municipality's responsibility will be the same as above, except that it will also be responsible for the total cost and acquisition of any right-of-way necessary to construct the new sidewalk.

Width

Where utilities or other appurtenances are present within 5 feet of the curb, the typical width of a sidewalk is 7 feet. Where no utilities are present, a sidewalk width of 5 feet is acceptable. The sidewalk width is measured from the face of the curb. Preferably, any roadside appurtenances (e.g., utility poles, traffic signs, fire hydrants) will be placed behind the sidewalk. In highly urbanized areas (central business districts), sidewalks are often paved from the back of the curb to the front edge of the building.

Cross Slopes

Typical cross slopes for sidewalks are 2.0% toward the roadway. Where necessary in restricted locations, a maximum cross slope of 8.0% may be used.

Curb-Cut Ramps

Curbs and sidewalks should be designed with curb-cut ramps at all pedestrian crosswalks to provide adequate access for the safe and convenient movement of physically handicapped persons. The following criteria should be considered in the design of curb-cut ramps:

1. At each intersection with pedestrian crosswalks (other than restoration/resurfacing projects), curb-cut ramps should be provided on all corners, even if outside project limits. At T-intersections, the designer should ensure that ramps are located on the side opposite the minor intersecting road.

2. Curb-cut ramps should be located or protected to prevent their obstruction by parked vehicles.

3. At marked pedestrian crosswalks, curb-cut ramps should be contained entirely within the markings, excluding any flared sides.

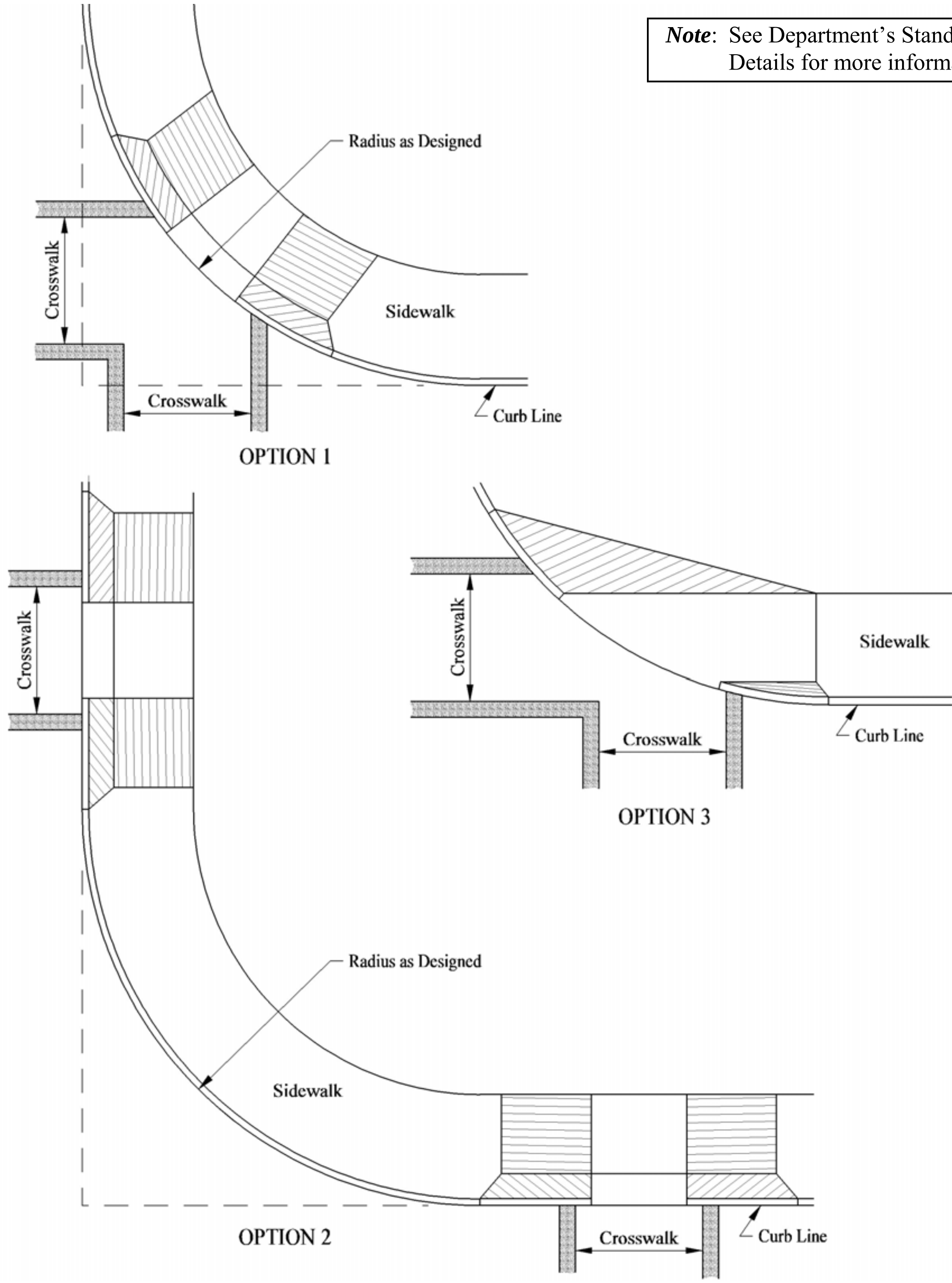
4. The function of the curb-cut ramps should not be compromised by other highway features (e.g., guardrail, catch basins, manholes).

5. The location of the ramp should be consistent with the operation of pedestrian-actuated traffic signals, if present. This should be confirmed with the Traffic Engineering Section.

Figure 6-4 provides a general plan view of the three types of available curb-cut ramps. Full details for the construction of curb-cut ramps at intersections are illustrated in the Department's Standard Details. The decision on when to use which type will be made on a case-by-case basis.

Slopes for ramps should not be greater than 12:1. The clear width of a ramp should be a minimum of 6 feet, exclusive of flared sides.

Note: See Department's Standard Details for more information.



CURB CUT RAMPS

Figure 6-4

6-2 MEDIANS

A median is desirable on many multilane highways. The principal functions of a median are to provide separation from opposing traffic, to prevent undesirable turning movements, to provide an area for deceleration and storage of left-turning vehicles, to provide space for snow storage and increased drainage collection, to provide an area for pedestrian refuge, and to provide width for future lanes.

6-2.01 Width

The median width is measured from the edge of the two inside travel lanes and includes the median shoulders if present. The designer should consider several factors when determining the appropriate median width:

1. Where applicable, the need for left-turn bays should be considered when selecting a median width.

2. A median should be approximately 25 feet wide to safely allow a crossing passenger vehicle to stop between the two roadways.

3. Turning movements at median openings depend on the median width and the width of the opening for cross traffic. These will dictate the turning characteristics (e.g., encroachment) of the various design vehicles which may make the turn.

4. A uniform median width is desirable; however, variable-width medians may be advantageous where right-of-way is restricted, at-grade intersections are widely spaced (0.5 mile or more), or an independent alignment is practical.

5. In general, the widths of the other roadway cross section elements should not be reduced to provide additional median width.

6-2.02 Type

The type of median selected depends on several factors including the availability for median width, left-turn demand, impacts of superelevation development, drainage, snow and ice impacts, rural or urban location and traffic volumes.

The following sections discuss the types of medians and recommended widths for design.

Flush Medians

A median is defined as a flush median when its vertical elevation above the surface of the adjacent roadway pavement is 1 inch or less. Flush medians are often used on urban highways and streets. The typical width of a flush median ranges from 2 feet to 6 feet. The median should be crowned to avoid ponding water on the median area. Continuous two-way, left-turn lanes are also considered flush medians. These are discussed in Section 8-5.

A flush median may also be used on urban freeways in conjunction with a concrete median barrier. The minimum width for this design is 14 feet (2 lanes in each direction) or 22 feet (3 or more lanes in each direction).

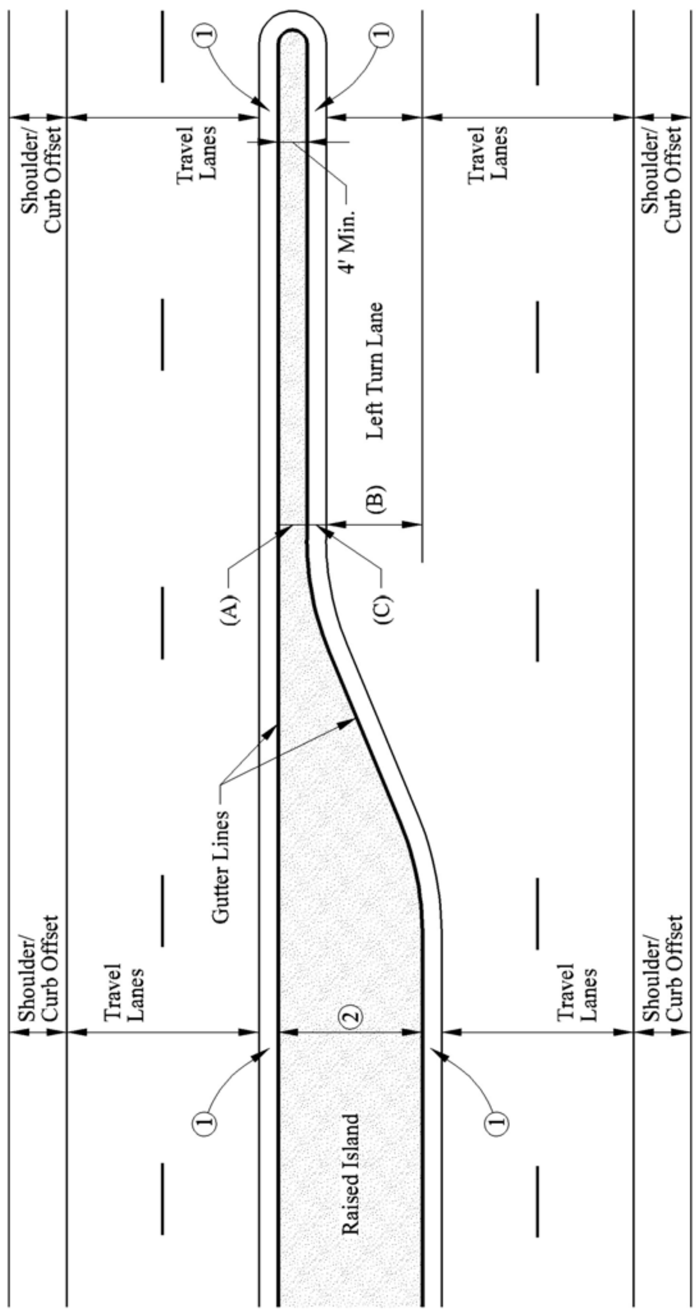
Raised Medians

Raised medians, typically with sloping curbs, are often used where it is desirable to control left turns. Desirably, the width of a raised median will be sufficient to accommodate left-turn lanes at intersections (see Figure 6-5). The minimum width of the raised island is 4 feet. Chapters Seven and Eleven provide criteria for auxiliary lane widths and for the minimum offset between the curb and travel lane. This curb offset should be maintained between the auxiliary lane and the raised island. Figure 6-10 illustrates a typical raised median section.

Depressed Medians

A depressed median is used where practical on freeways and divided arterials. Depressed medians have better drainage and snow storage characteristics and, therefore, are preferred on major highways. Depressed medians should be as wide as practical to allow for the addition of future travel lanes on the inside while maintaining a sufficient median width. The minimum width of a depressed median should be the sum of the left shoulder widths plus 14 feet. This width allows a sufficient depth of median ditch for drainage, and it allows the future addition of 10-foot left shoulders if additional travel lanes are provided on the outside of the roadway section.

Figures 6-7 and 6-8 illustrate the typical cross section of a depressed median. The typical slope is 6:1 and a 10-foot vertical curve is normally used in the center of the median. However, if a median barrier is warranted in the depressed median, the slope in front of the barrier cannot exceed 10:1. See Figure 6-12. If a steeper slope is used, two separate runs of guardrail should be used instead of the median barrier. See Section 10-6 for more discussion on median barriers.



1 See Chapters Seven and Eleven for left-turn (auxiliary) lane width and curb offset width criteria.

2 This dimension should be the sum of the raised island width (A) (gutter line to gutter line) at the left-turn lane plus the left-turn lane width (B) plus the curb offset width (C) between the left-turn lane and the raised island.

DESIRABLE MEDIAN WIDTH
(Urban Arterial with Raised Median)

Figure 6-5

DESIRABLE MEDIAN WIDTH
(Urban Arterial with Raised Median)

Figure 6-5

6-3 ROADSIDE ELEMENTS

6-3.01 Fill Slopes

Fill slopes are the slopes extending outward and downward from the edge of the shoulder to intersect the natural ground line. Figures 6-7 to 6-11 illustrate the Department's criteria. These are summarized as follows:

1. ***Freeways (Figure 6-7)***. The following applies:

    a. Embankment height < 20 feet. The Department uses a variable fill slope on urban and rural freeways. A 6:1 slope is provided to the roadside clear zone or to the intersection with the subgrade, whichever is the greater distance. A 4:1 slope is provided from the hinge point to the ground line.

    b. Embankment height ≥ 20 feet. A 2:1 slope with guardrail is typical.

2. ***Other Rural Highways (Figures 6-8 and 6-9)***. Table 6-1 summarizes the Department's criteria.

Functional Class	**Embankment Height**	**Fill Slope**
Divided Arterials (Non-Freeways)	< 20 ft ≥ 20 ft	4:1 2:1
Two-Lane Arterials	< 15 ft ≥ 15 ft	4:1 2:1
Collector/ Local	< 15 ft ≥ 15 ft	3:1 2:1

Note: Guardrail is required on 2:1 fill slopes.

TYPICAL FILL SLOPES ON NON-FREEWAYS

Table 6-1

3. ***Other Urban Highways and Streets (Figures 6-10 and 6-11).*** For curbed sections, either a sidewalk or a minimum 3-foot "shelf" area is used before the fill slope begins. Beyond the sidewalk or shelf area, the criteria in Table 6-1 will apply. On urban highways and streets without curbs, neither a sidewalk nor shelf area will typically be provided. The criteria in Table 6-1 will also apply to uncurbed facilities.

Where fill slope transitions are necessary (e.g., 4:1 to 3:1), the transition should be made as illustrated in Figure 6-6.

6-3.02 Earth Cuts

Uncurbed Roads (Ditch Sections)

In earth cuts where curb is not warranted, a roadside ditch will be provided. The following criteria will apply to earth cuts on uncurbed roads:

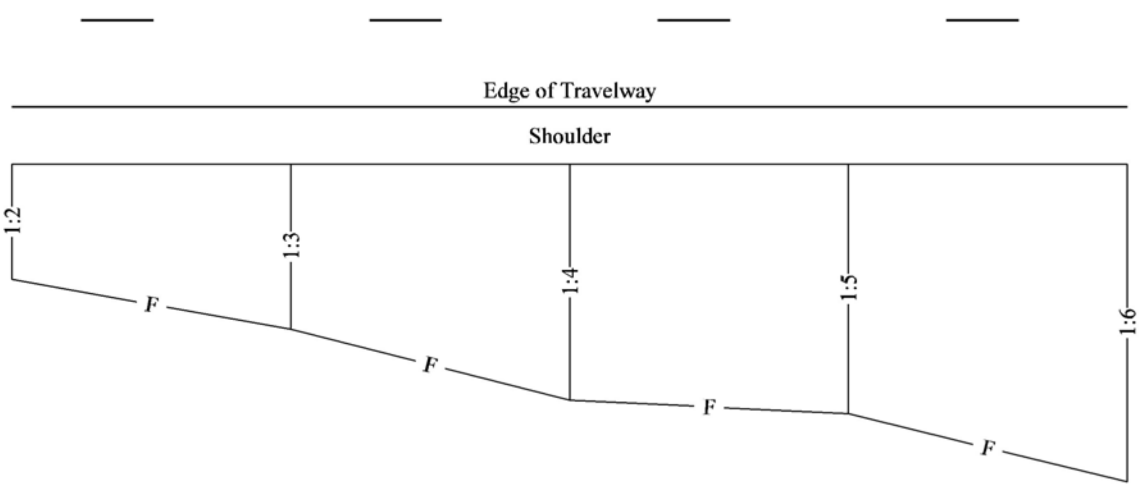
1. ***Freeways (Figure 6-7)***. The Department uses a 6:1 front slope and 3:1 back slope with a ditch bottom shaped by a 10-foot vertical curve. As illustrated in Figure 6-7, the vertical curve is based upon a 4:1 front slope; this produces a "hinge" between the 6:1 front slope and the ditch. The flow line of the ditch should be 1 foot below the roadway subgrade. Where large volumes of runoff are expected, interception ditches may be necessary along the toe of back slope in a cut section. Berm ditches are formed with sufficient capacity to accommodate a 50-year design flood frequency.

2. ***Other Roads (Figures 6-8 and 6-9)***. On all other roads without curbs, a V-ditch is normally used. If needed for hydraulic capacity, a trapezoidal ditch may be used. For V-ditches the typical front slope is 4:1 on arterials and 3:1 on collector and local roads. The typical back slope is 2:1 in earth cuts.

Curbed Sections (Figures (6-10 and 6-11)

Highways and streets with curbs will have either a sidewalk or 3 to 5-foot shelf area behind the curb. The back slope in an earth cut will vary to meet field conditions.

From	To	Transition Length
6:1	4:1 3:1 2:1	100 ft 150 ft 200 ft
4:1	6:1 3:1 2:1	100 ft 50 ft 100 ft



FILL SLOPE TRANSITIONS

Figure 6-6

6-3.03 Ledge Rock Cuts

Figures 6-7, 6-8 and 6-9 provide the details for the ledge rock cut. These criteria will be based on type of facility (freeway or non-freeway) and the height of the ledge rock cut (more or less than 6 feet).

6-3.04 Landscaping

The following will apply to the landscaping plan for Department projects.

Replacement Trees

Replacement trees are typically included on urban projects with streetscape design. They could be used to aid in property owner settlements. Any design should be done with consultation with Landscape and Right-of-Way Team members.

Snow Fences

Plantings for snow fences may be required in special cases (e.g., in Aroostook County or along developed property on bypasses where the roadway will be much closer). The Maintenance Division, during field inspections, or the Landscaping Section will identify candidate locations in Aroostook County. Other locations will be identified in the plan submittal to the Landscape Division.

Landscaping Plans (Urban Areas)

On projects which reconstruct or rehabilitate streets in urban areas (residential and non-residential), a landscaping plan should be seriously considered. This often refers to providing a "Tree-Lined Street or Roadway." The following will apply to landscaping plans:

1. ***Highway Recommendation Form***. The potential for a landscaping plan should be identified in the Highway Recommendation Form. The Project Leader and/or designer will request that the Landscaping Section provide a landscaping plan and estimate, which will be included in the project PDR.

2. ***Project Integration***. Typically, if a landscaping plan will be developed, it will not be advertised separately but as a part of the roadway construction project.

3. ***Coordination***. Other Department units should be made aware of any proposed tree locations. Examples of needed coordination include the Right-of-Way Division for any plantings on public and private property and the Utility Section for the location of overhead lines.

6-4 BRIDGE AND UNDERPASS SECTIONS

The highway cross section should be carried over and under bridges depending on the cross section of the approaching roadway, its functional classification and the project scope of work. Chapters Seven and Eleven present the detailed criteria for the width of the roadway cross section.

6-4.01 Bridges

The Bridge Program, in coordination with the Urban & Arterial Highway Program, will determine the roadway width which will be carried across the bridge.

6-4.02 Underpasses

On all highways, the approaching highway cross section, preferably including clear zones, should be carried through the underpass. Where clear zone distances cannot be provided through the underpass, a roadside barrier may be necessary (see Section 10-2). See also AASHTO page 280.

6-4.03 Transitions

When lane and shoulder transitions are required at bridge and underpass sections, the taper length of the roadway transition should be determined from the following equations:

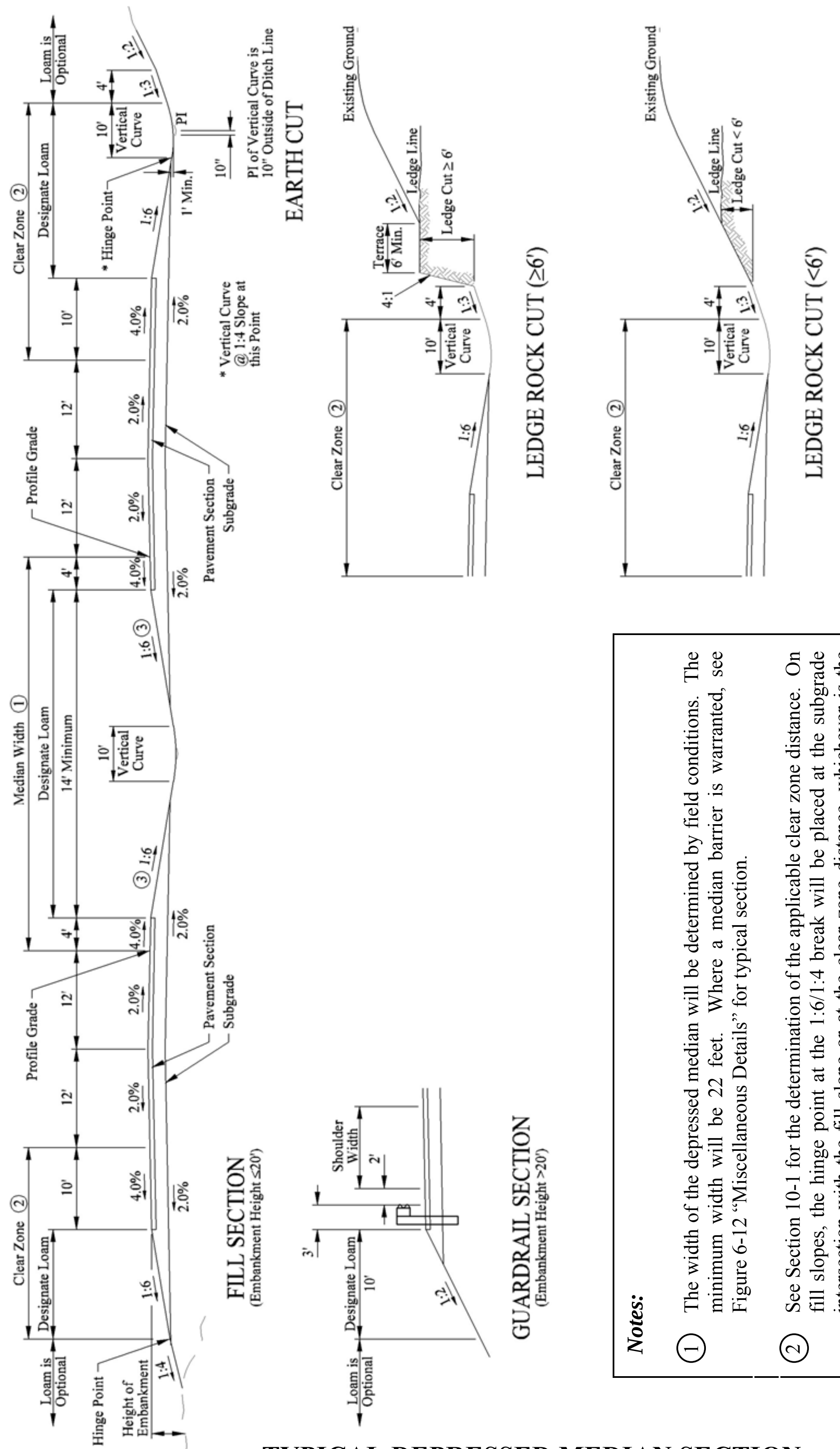
1. $L = WS$ ($S > 45$ mph)
2. $L = WS^2/60$ ($S \leq 45$ mph)

Where:
L = taper length, ft
W = width of transition, ft
S = design speed, mph

6-5 TYPICAL SECTIONS

The following figures present typical sections which will apply to all new construction and reconstruction projects. Chapter Eleven discusses how these criteria may be modified on rehabilitation and restoration/resurfacing projects on non-freeways. The typical section figures are:

1. Figure 6-7 "Typical Depressed Median Section (Freeways)."
2. Figure 6-8 "Typical Depressed Median Section (Non-Freeways)."
3. Figure 6-9 "Typical Two-Lane Rural Highway."
4. Figure 6-10 "Typical Raised Median Section (Urban Arterials)."
5. Figure 6-11 "Typical Two-Lane Urban Street (Uncurbed)."
6. Figure 6-12 "Miscellaneous Details."



Notes:

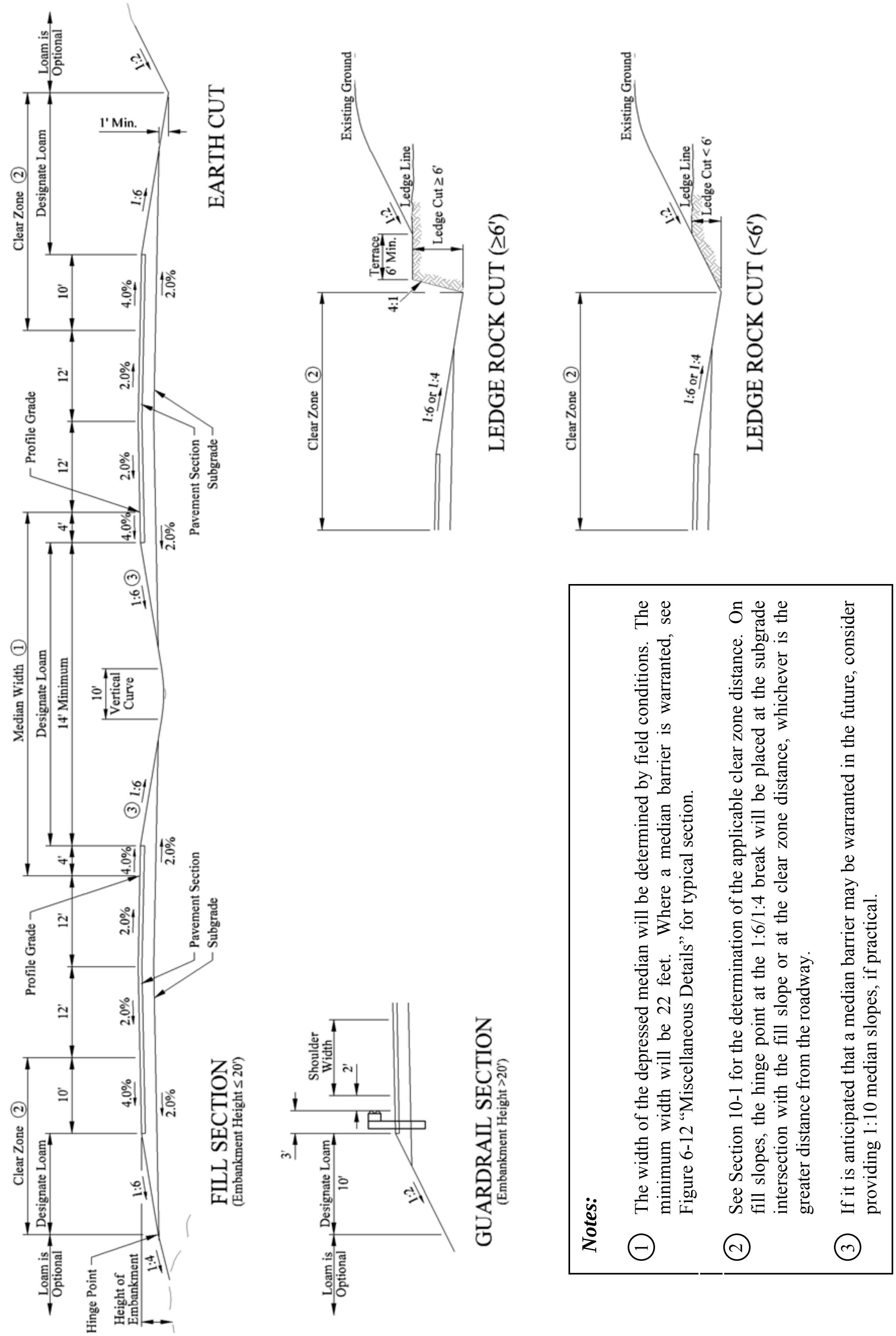
1. The width of the depressed median will be determined by field conditions. The minimum width will be 22 feet. Where a median barrier is warranted, see Figure 6-12 "Miscellaneous Details" for typical section.
2. See Section 10-1 for the determination of the applicable clear zone distance. On fill slopes, the hinge point at the 1:6/1:4 break will be placed at the subgrade intersection with the fill slope or at the clear zone distance, whichever is the greater distance from the roadway.
3. If it is anticipated that a median barrier may be warranted in the future, consider providing 1:10 median slopes, if practical.

TYPICAL DEPRESSED MEDIAN SECTION
(Freeways)

Figure 6-7

TYPICAL DEPRESSED MEDIAN SECTION
(Freeways)

Figure 6-7



Notes:

① The width of the depressed median will be determined by field conditions. The minimum width will be 22 feet. Where a median barrier is warranted, see Figure 6-12 "Miscellaneous Details" for typical section.

② See Section 10-1 for the determination of the applicable clear zone distance. On fill slopes, the hinge point at the 1:6/1:4 break will be placed at the subgrade intersection with the fill slope or at the clear zone distance, whichever is the greater distance from the roadway.

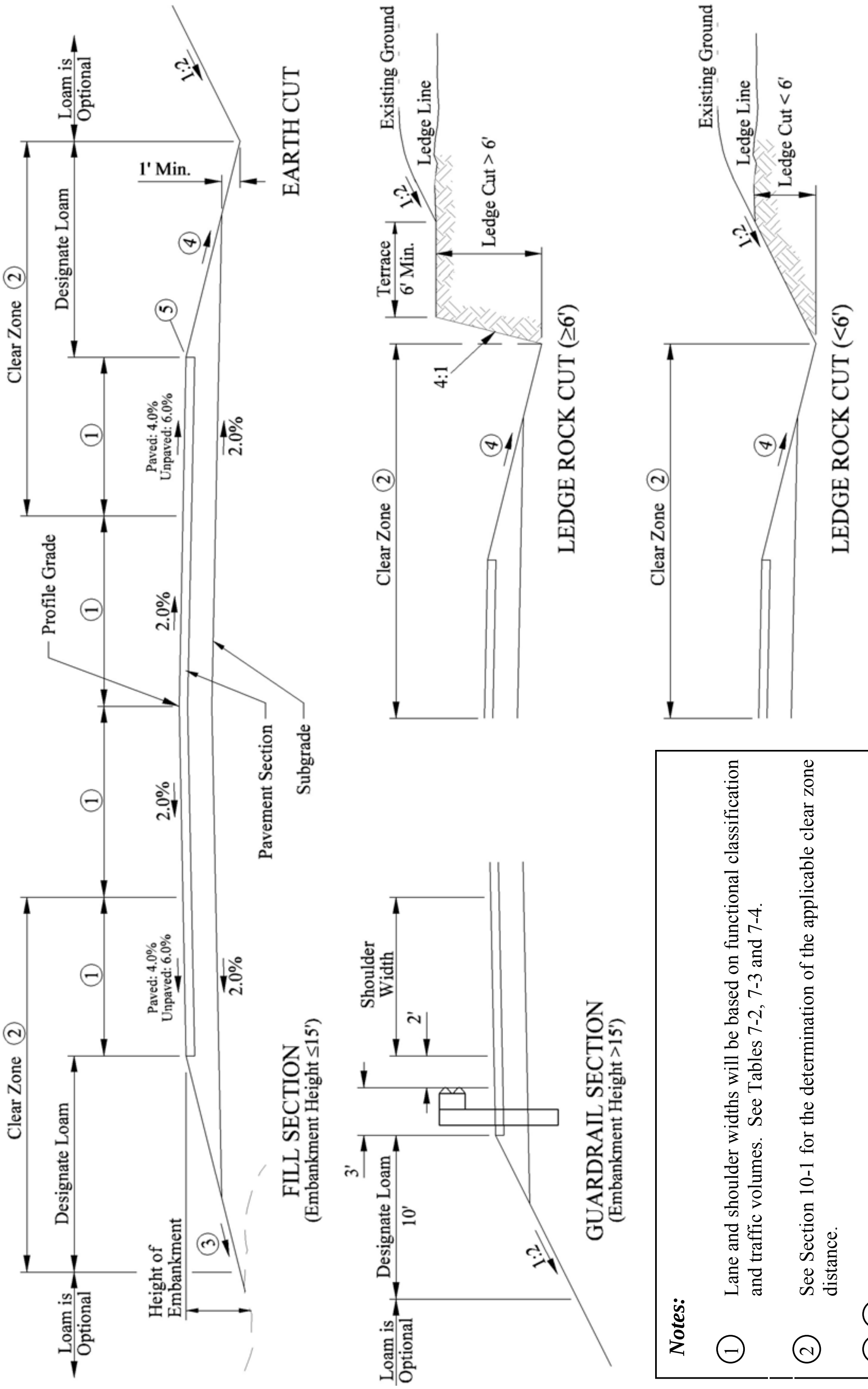
③ If it is anticipated that a median barrier may be warranted in the future, consider providing 1:10 median slopes, if practical.

TYPICAL DEPRESSED MEDIAN SECTION
(Non-Freeways)

Figure 6-8

TYPICAL DEPRESSED MEDIAN SECTION
(Non-Freeways)

Figure 6-8



Notes:

① Lane and shoulder widths will be based on functional classification and traffic volumes. See Tables 7-2, 7-3 and 7-4.

② See Section 10-1 for the determination of the applicable clear zone distance.

③ ④ Fill slope and ditch front slope will be based on functional classification and traffic volumes. See Tables 7-2, 7-3 and 7-4.

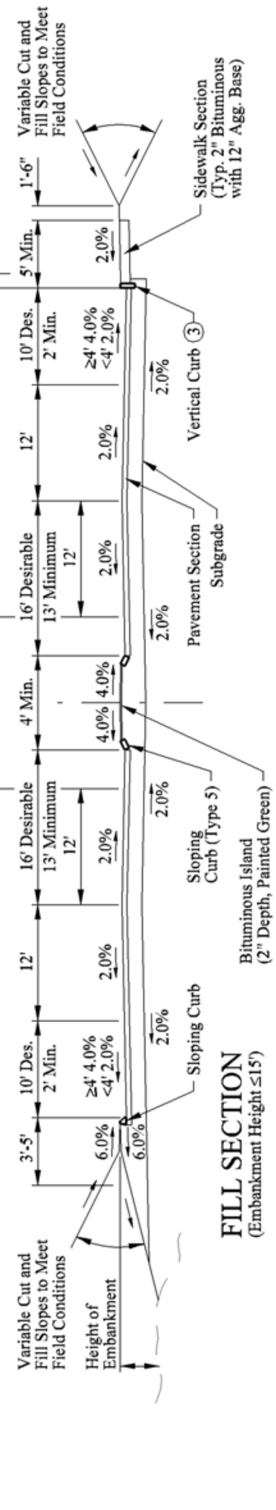
⑤ If a curbed section is used on a rural road, see Figure 6-11 for details.

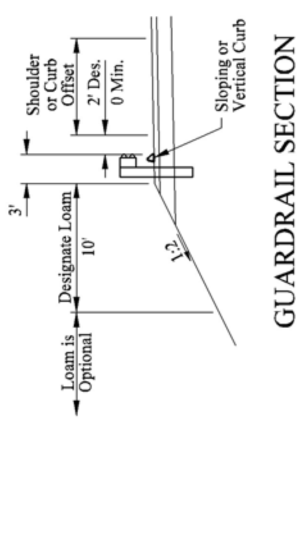
TYPICAL TWO-LANE RURAL HIGHWAY
(Arterials, Collectors and Local Roads)

Figure 6-9

TYPICAL TWO-LANE RURAL HIGHWAY
(Arterials, Collectors and Local Roads)

Figure 6-9





Notes:

1. The median width will be determined by the width of the raised island plus the shoulder width or curb offset on either side of the raised island. See section 6-2 for more discussion on the width of raised medians. In addition to raised medians, a flush median or a continuous two-way, left-turn lane may be used on an urban arterial.

2. Where utilities or other appurtenances are present within the sidewalk, the typical width of the sidewalk is 7 feet. See Figure 6-12 for a typical sidewalk section with a buffer area.

3. A vertical curb should be used where sidewalks are present. Where there is no curb or sidewalk, the roadside design will be according to the criteria for rural arterials. See Figure 6-9 and Table 7-2.

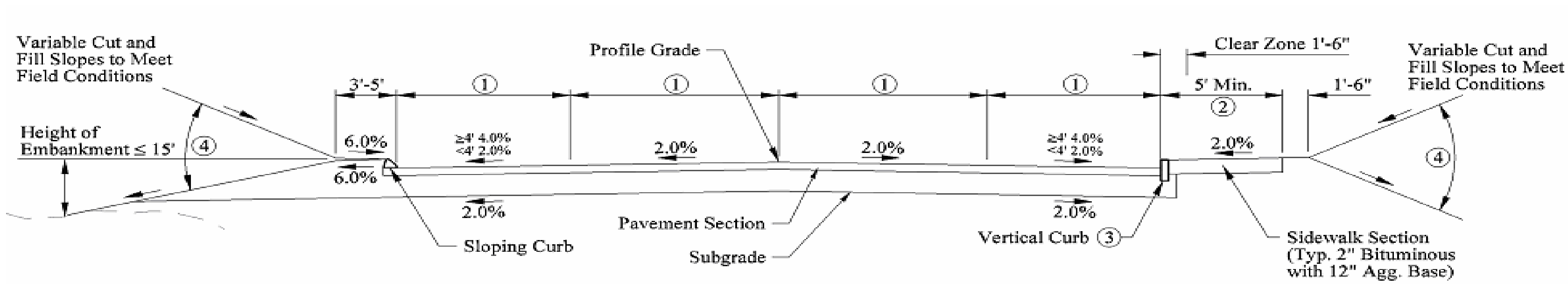
4. See Section 6-3 for more information.

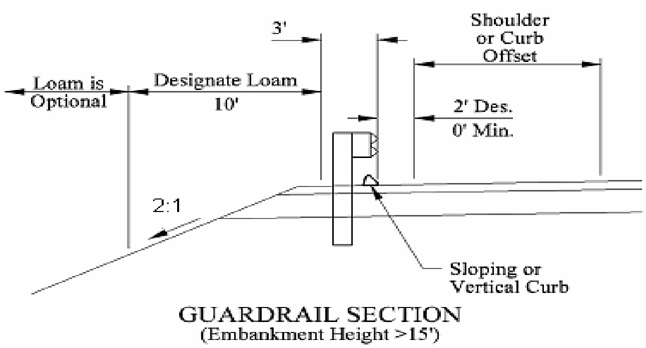
TYPICAL RAISED MEDIAN SECTION
(Urban Arterials)

Figure 6-10

TYPICAL RAISED MEDIAN SECTION
(Urban Arterials)

Figure 6-10





Notes:

1 Lane and shoulder/curb offset widths will be based on functional classification. See Tables 7-5, 7-6 and 7-7.

2 Where utilities or other appurtenances are present within the sidewalk, the typical width of the sidewalk is 7 feet. See Figure 6-12 for a typical sidewalk section with a buffer area.

3 A vertical curb should be used where sidewalks are present. Where there is no curb or sidewalk, the roadside design will be according to the criteria for rural arterials. See Figure 6-9 and Table 7-2.

4 Cut and fill slopes should be as flat as practical. In earth cuts, a 2:1 maximum back slope will apply; in rock cuts, a 1/4:1 maximum will apply. On fills up to 15 feet in height, a 4:1 maximum slope will apply to arterials, and a 3:1 maximum slope will apply to collector and local streets. On fills greater than 15 feet, the "Guardrail Section" will apply.

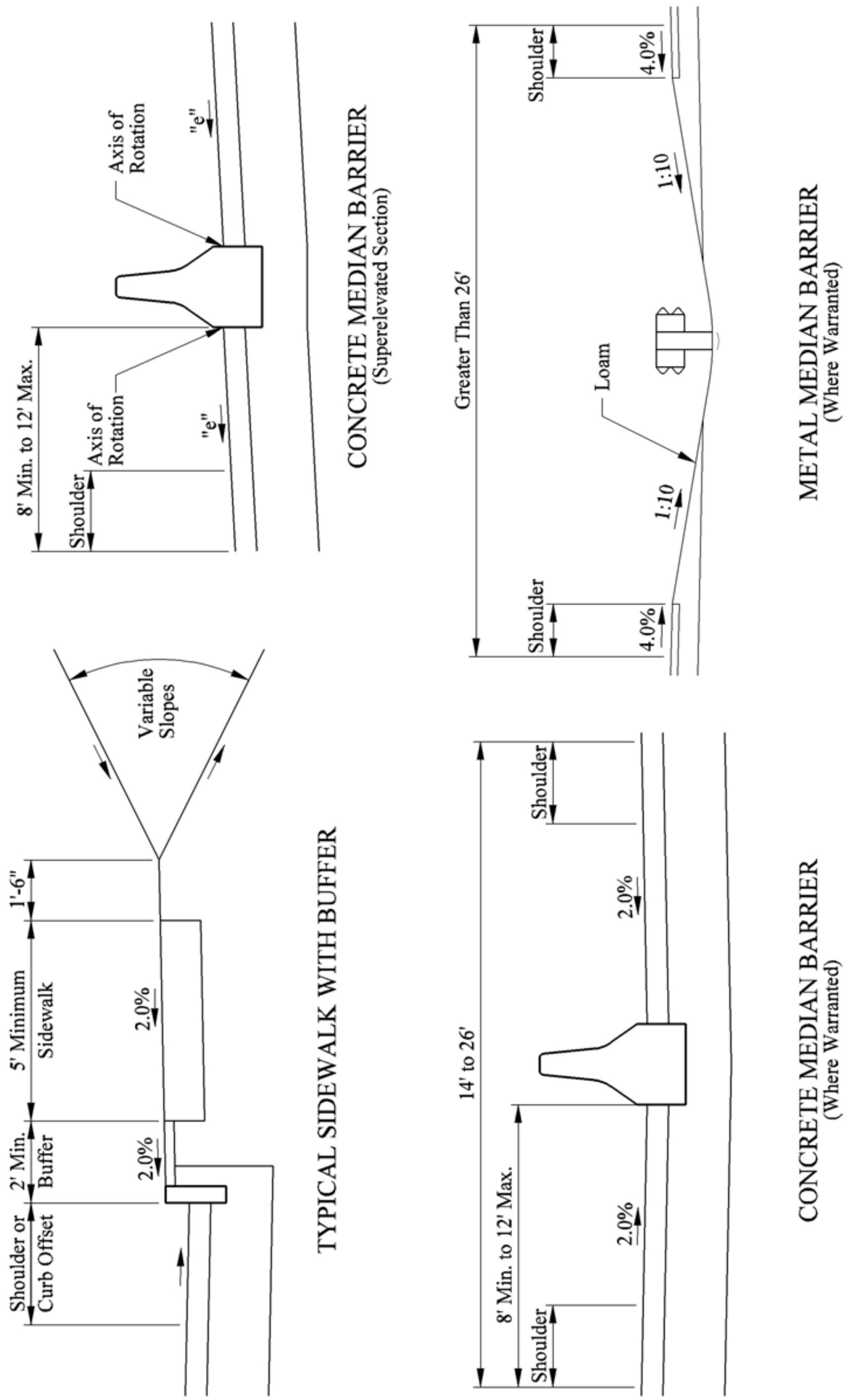
5 See Section 6-3 for more information.

TYPICAL TWO-LANE URBAN STREET
(Curbed)

Figure 6-11

TYPICAL TWO-LANE URBAN STREET
(Curbed)

Figure 6-11



MISCELLANEOUS DETAILS

Figure 6-12

MISCELLANEOUS DETAILS

Figure 6-12

CHAPTER SEVEN

GEOMETRIC DESIGN TABLES
(New Construction/Reconstruction)

Volume I

- Highway Design Guide –

National Standards

<u>December 2004</u>

Chapter Seven

TABLE OF CONTENTS

Chapter Seven

GEOMETRIC DESIGN TABLES
(New Construction/Reconstruction)

This chapter presents the Department's criteria for the design of new construction and reconstruction projects. The designer should consider the following in the use of the tables:

1. ***Functional Classification***. The selection of design values for new construction and reconstruction depends on the functional classification of the highway facility. This is discussed in Section 3-2. For Minor Arterial or Lower classifications see the State Standard Highway Design Guide.

2. ***Cross Section Elements***. The designer should realize that some of the cross section elements included in a table (e.g., median width) are not automatically warranted in the project design. The values in the tables will only apply after the decision has been made to include the element in the highway cross section.

3. ***Manual Section References***. These tables are intended to provide a concise listing of design values for easy use. However, the designer should review the manual section references for greater insight into the design elements.

4. ***Footnotes.*** The tables include many footnotes, which are identified by a number in parentheses (e.g., (6)). The information in the footnotes is critical to the proper use of the design tables.

	Design Element			Manual Section	Rural	Urban		
DESIGN CONTROLS	*Design Speed			3-4	70 mph	55-70 mph		
	Access Control			3-5	Controlled Access	Controlled Access		
	Level of Service			3-3	B	Desirable: B Minimum: C		
CROSS SECTION ELEMENTS	*Lane Width			6-1	12'	12'		
	*Shoulder Width		Right	6-1	10'	10'		
			Left	6-1	4' (1)	4' (1)		
	Cross Slope		*Travel Lane	6-1	2.0%	2.0%		
			Shoulder	6-1	4.0%	4.0%		
	Auxiliary Lane Width (2)			6-1	12'	12'		
	Median Width			6-2	Depressed: (3)	Flush: 14' min. w/CMB Depressed: (3)		
	*New and Rehabilitated Bridges		Structural Capacity	~	SEE BRIDGE PROGRAM	SEE BRIDGE PROGRAM		
			Minimum Width	~				
	*Existing Bridges to Remain in Place		Structural Capacity	~				
			Minimum Width	~				
	Clear Zone			10-1	(4)	(4)		
	Side Slopes	Cut	Front Slope	6-3	1:6	1:6		
			Depth of Ditch	6-3	(5)	(5)		
			Back Slope	6-3	1:2 (6)	4'2 (6)		
		Fill	0 - 20' Height	6-3	1:6/1:4 (hinged) (7)	1:6/1:4 (hinged) (7)		
			> 20' Height	6-3	1:2	1:2		
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (8)			4-1	730'	55 mph	60 mph	70 mph
						495'	570'	730'
	Decision Sight Distance (9)			4-1	1105'	1135'	1280'	1445'
	*Maximum Degree of Curve (e = 6.0%)			5-2	2° 45'	5° 15'	4° 15'	2° 45'
	*Superelevation Rate			5-2	Table 5-6 (e_{max} = 6.0%)	Table 5-6 (e_{max} = 6.0%)		
	*Horizontal Sight Distance			5-2	(10)	(10)		
	*Maximum Profile Grades (11)		Level	4-2	3%	4%	3%	3%
			Rolling	4-2	4%	5%	4%	4%
			Mountainous	4-2	5%	6%	6%	5%
	Minimum Profile Grades			4-2	Desirable: 0.25% Minimum: 0%	Desirable: 0.25% Minimum: 0%		
	*Minimum Vertical Clearance (12)		New and Replaced Overpassing Bridges	4-3	16'-6"			
			Existing Overpassing Bridges	4-3	16'-0"			

* Controlling design criteria (See Section 3-7).

GEOMETRIC DESIGN CRITERIA FOR FREEWAYS
(New Construction/Reconstruction)

Table 7-1

GEOMETRIC DESIGN CRITERIA FOR FREEWAYS

(New Construction/Reconstruction)

Footnotes to Table 7-1

1. Shoulder Width (Left Shoulder). Where a concrete median barrier is used, the minimum left shoulder is 6' for freeways with two lanes in one direction. For all freeways with three or more lanes in one direction, it is desirable to use a 10' left shoulder.

2. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should equal the shoulder width normally provided adjacent to the travel lane.

3. Median Width (Depressed). Median widths for depressed sections should be determined by field conditions (see Figure 6-7).

4. Clear Zone. Clear zone will vary according to design speed, traffic volume and side slope. See Section 10-1.

5. Depth of Ditch. A rounded ditch section should be used unless hydraulic capacity warrants the use of a trapezoidal ditch. See Figure 6-7. Maintain the depth of ditch 1'below subgrade. If this criteria (1' below subgrade) determines the horizontal location of the ditch flow line, the calculated horizontal distance to the flow line will be rounded up to the next highest 6 inch increment.

6. Back Slope. The Department's typical practice is to place the toe of the back slope outside of the clear zone. See the typical section figures in Section 6-5 and the clear zone discussion in Section 10-1. In rock cuts, the back slope may be as steep as 4:1. See rock cut detail in Figure 6-7.

7. Fill Slope (Height: 0-20'). See Figure 6-7 for an illustration of the 6:1/4:1 hinged fill slope. The hinge point will be placed at the subgrade intersection with the fill slope or at the clear zone distance, whichever is the greatest distance from the roadway. If a barrier is warranted on the fill slope (e.g., for roadside obstacles), use a 2:1 fill slope with guardrail. See Section 10-2 for roadside barrier warrants.

8. Minimum Stopping Sight Distance. If practical, values in the columns may be adjusted for grades (see Table 4-1).

9. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

10. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and stopping sight distance (see Section 5-2).

11. Maximum Grades. Grades 1 percent steeper may be used in restricted urban areas where development precludes the use of flatter grades. Grades 1 percent steeper may also be used for one-way downgrades, except in mountainous terrain.

12. Minimum Vertical Clearance. The vertical clearances apply to the freeway passing under. For the 16'-6" clearance, 6" is provided for future resurfacing. The minimum vertical clearance is 17'-6" for the freeway passing under a new pedestrian bridge or new sign truss. The clearance is 17'-0" for the freeway passing under an existing pedestrian bridge or existing sign truss. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the freeway.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances

Design Element				Manual Section	2 - Lane				Multilane	
			AADT (1)		Under 400	400 - 1500	Over 1500			
			DHV (1)			100 - 200	201 - 400	Over 400	Divided	Undivided
DESIGN CONTROLS	*Design Speed (2)			3-4	55-60 mph				55-60 mph	
	Access Control			3-5	Entrance Control				Entrance Control	
	Level of Service			3-3	B				B	
CROSS SECTION ELEMENTS	*Lane Width (3a)			6-1	12' (3b)		12'		12'	
	*Shoulder Width (4)		Right	6-1	4'	6'	8'	8'-10'	10'	
			Left	6-1	N/A				4'	N/A
	Cross Slope		*Travel Lane	6-1	2.0%				2.0%	
			Shoulder	6-1	4.0%				4.0%	
	Auxiliary Lane Width (2)			6-1	12'				12'	
	Median Width			6-2	N/A				(6)	N/A
	*New and Rehabilitated Bridges		Structural Capacity	~	SEE BRIDGE PROGRAM				SEE BRIDGE PROGRAM	
			Minimum Width	~						
	*Existing Bridges to Remain in Place		Structural Capacity	~						
			Minimum Width	~						
	Clear Zone			10-1	(7)				(7)	
	Side Slopes	Cut	Front Slope	6-3	1:4				1:4	
			Depth of Ditch	6-3	(8)				(8)	
			Back Slope	6-3	1:2 (9)				1:2 (9)	
		Fill	0 - 15' Height	6-3	1:4 (10)				1:4 (10)	
			> 15' Height	6-3	1:2				1:2	
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (11)			4-1	50 mph			55 mph		60 mph
					425'			495'		570'
	Passing Sight Distance			4-1	1835'			1985'		2135'
	Decision Sight Distance (12)			4-1	750'			865'		990'
	*Maximum Degree of Curve (e = 6.0%)			5-2	6° 45'			5° 15'		4° 15'
	*Superelevation Rate			5-2	Table 5-6 (e_{max} = 6.0%)					
	*Horizontal Sight Distance			5-2	(13)					
	*Maximum Profile Grades (14)		Level	4-2	4%			4%		3%
			Rolling	4-2	5%			5%		4%
			Mountainous	4-2	7%			6%		6%
	Minimum Profile Grades			4-2	Desirable: 0.25%				Minimum: 0%	
	*Minimum Vertical Clearance (15)		New and Replaced Overpassing Bridges	4-3	Desirable: 16'-6"				Minimum: 16'-0"	
			Existing Overpassing Bridges	4-3	14'-0"					

* Controlling design criteria (See Section 3-7).

GEOMETRIC DESIGN CRITERIA FOR RURAL ARTERIALS
(New Construction/Reconstruction)

Table 7-2

GEOMETRIC DESIGN CRITERIA FOR RURAL ARTERIALS
(New Construction/Reconstruction)

Footnotes to Table 7-2

1. Traffic Volumes. AADT and DHV values are projected to the design year, normally 20 years from the expected construction completion date.

2. Design Speed. For two-lane highways in mountainous terrain, a 50 mph design speed may be used. For all highways, the design speed should equal or exceed the anticipated posted or regulatory speed limit after construction.

3. Lane Widths. The following will apply:

   a. For a 50 mph design speed and for AADT under 400, lane widths may be 11' on two-lane highways.

   b. Existing 11'lanes on reconstructed highways may be retained if alignment and safety record are satisfactory.

4. Shoulder Width (Curbed Facilities). On rural arterials where curbs are provided, it is desirable to increase a proposed 4'or 6' shoulder by an additional 2'. Proposed 8'or 10' shoulders do not need to be adjusted when curbs are introduced.

5. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 4'desirable and 2'minimum.

6. Median Width. Where medians are warranted, the width should be determined by design requirements and field conditions.

7. Clear Zone. Clear zone will vary according to design speed, traffic volume and side slope. See Section 10-1.

8. Depth of Ditch. A "V" ditch section should be used unless hydraulic capacity warrants the use of a trapezoidal ditch. Maintain the depth of ditch 1' below subgrade. If this criteria (1' below subgrade) determines the horizontal location of the ditch flow line, the calculated horizontal distance to the flow line will be rounded up to the next highest 6" increment.

9. Back Slope. The Department's typical practice is to place the toe of the back slope outside of the clear zone. See the typical section figures in Section 6-5 and the clear zone discussion in Section 10-1. In rock cuts, the back slope may be as steep as 4:1. See rock cut detail in Figure 6-12.

10. Fill Slopes (0-15' Height). If guardrail is warranted for reasons other than the fill slope, use a 2:1 slope in combination with the guardrail rather than a 4:1 slope.

11. Minimum Stopping Sight Distance. If practical, values in the columns may be adjusted for grades (see Table 4-1).

12. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

13. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and stopping sight distance (see Section 5-2).

14. Maximum Grades. Grades 1 percent steeper may be used on one-way downgrades on divided facilities.

15. Minimum Vertical Clearance. The vertical clearances apply to the arterial passing under. For the 16'-6" clearance, 6" is provided for future resurfacing. The minimum vertical clearance is 17'-6" for the arterial passing under a new sign truss. The clearance is 17'-0" for the arterial passing under an existing sign truss. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the arterial.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances

	Design Element		AADT (1)	Manual Section	Under 400	400 - 1500	1500 - 2000	Over 2000
DESIGN CONTROLS	*Design Speed (2)		Level	3-4	40 mph	50 mph	50 mph	55-60 mph
			Rolling	3-4	30 mph	40 mph	40 mph	50 mph
			Mountainous	3-4	30 mph	30 mph	30 mph	40 mph
	Access Control			3-5	Entrance Control			
	Level of Service			3-3	Desirable: B		Minimum: C	
CROSS SECTION ELEMENTS	*Lane Width			6-1	10'	11'	11'	12'
	*Shoulder Width (3)			6-1	4'	6'	8'	
	Cross Slope		*Travel Lane	6-1	2.0%			
			Shoulder	6-1	Paved: 4.0%		Unpaved: 6.0%	
	Auxiliary Lane Width (4)			6-1	10'	11'		
	*New and Rehabilitated Bridges		Structural Capacity	~	SEE BRIDGE PROGRAM		SEE BRIDGE PROGRAM	
			Minimum Width	~				
	*Existing Bridges to Remain in Place		Structural Capacity	~				
			Minimum Width	~				
	Clear Zone			10-1	(5)			
	Side Slopes	Cut	Front Slope	6-3	1:3		1:4	
			Depth of Ditch	6-3	(6)			
			Back Slope	6-3	1:2 (7)			
		Fill	0 - 15' Height	6-3	1:3		1:4	
			> 15' Height	6-3	1:2 (8)			

	Design Element	AADT (1)	Manual Section						
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (9)		4-1	30 mph	35 mph	45 mph	50 mph	55 mph	60 mph
				200'	250'	360'	425'	495'	570'
	Passing Sight Distance		4-1	1090'	1280'	1625'	1835'	1985'	2135'
	Decision Sight Distance (10)		4-1	450'	525'	675'	750'	865'	990'
	*Maximum Degree of Curve (e = 6.0%)		5-2	21° 00'	15° 00'	8° 45'	6° 45'	5° 15'	4° 15'
	*Superelevation Rate		5-2	Table 5-6 (e_{max} = 6.0%)					
	*Horizontal Sight Distance		5-2	(11)					
	*Maximum Profile Grades	Level	4-2	7%	7%	7%	6%	6%	5%
		Rolling	4-2	9%	9%	8%	7%	7%	6%
		Mountainous	4-2	10%	10%	10%	9%	9%	8%
	Minimum Profile Grades		4-2	Desirable: 0.25%			Minimum: 0%		
	*Minimum Vertical Clearance (12)	New and Replaced Overpassing Bridges	4-3	Desirable: 15'-6"			Minimum: 15'-0"		
		Existing Overpassing Bridges	4-3	14'-0"					

* Controlling design criteria (See Section 3-7).

GEOMETRIC DESIGN CRITERIA FOR RURAL COLLECTOR ROADS
(New Construction/Reconstruction)

Table 7-3

GEOMETRIC DESIGN CRITERIA FOR RURAL COLLECTOR ROADS
(New Construction/Reconstruction)

Footnotes to Table 7-3

1. Traffic Volumes. The AADT is determined for a future year, usually 20 years beyond the construction completion date.

2. Design Speed. Minimum values for design speed are presented. The designer should provide higher values where conditions allow. In addition, the design speed should equal or exceed the posted or regulatory speed limit of the completed facility.

3. Shoulder Width. The criteria refer to the paved shoulder width, if applicable, or to the graded shoulder width, if unpaved. The graded shoulder width is the distance between the edge of travel lane and the point of intersection of the shoulder slope and side slope.

   On rural collectors where curbs are provided, it is desirable to increase a proposed 4' or 6' shoulder by an additional 2'. Proposed 8' shoulders do not need to be adjusted when curbs are introduced.

4. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 4'desirable and 2'minimum.

5. Clear Zone. Clear zone will vary according to design speed, traffic volume and side slope. See Section 10-1.

6. Depth of Ditch. A "V" ditch section should be used unless hydraulic capacity warrants the use of a trapezoidal ditch. Maintain the depth of ditch 1' below subgrade. If this criteria (1' below subgrade) determines the horizontal location of the ditch flow line, the calculated horizontal distance to the flow line will be rounded up to the next highest 6" increment.

7. Back Slope. The Department's typical practice is to place the toe of the back slope outside of the clear zone. See the typical section figures in Section 6-5 and the clear zone discussion in Section 10-1. In rock cuts, the back slope may be as steep as 4:1. See rock cut detail in Figure 6-12.

8. Fill Slope (Height >15'). A 1.75:1 slope may be allowed to avoid significant right-of-way and/or environmental concerns.

9. Minimum Stopping Sight Distance. If practical, values in the columns may be adjusted for grades (see Table 4-1).

10. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

11. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and stopping sight distance (see Section 5-2).

12. Minimum Vertical Clearance. The vertical clearances apply to the collector passing under. For the 15'-6" clearance, 6" is provided for future resurfacing. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the collector.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances

	Design Element	AADT (1)	Manual Section	Under 250	250 - 400	400 - 1500	1500 - 2000	Over 2000	
DESIGN CONTROLS	*Design Speed (2)	Level	3-4	30 mph	35-45 mph	50 mph			
		Rolling	3-4	30 mph	30 mph	40 mph			
		Mountainous	3-4	20 mph	20 mph	30 mph			
	Access Control		3-5	Entrance Control					
	Level of Service		3-3	C					
CROSS SECTION ELEMENTS	*Lane Width		6-1	10'		<40 mph: 10' >40 mph: 11'	11'	12'	
	*Shoulder Width (3)		6-1	2' (3a)		6' (3b)	8'		
	Cross Slope	*Travel Lane	6-1	2.0%					
		Shoulder	6-1	Paved: 4.0%			Unpaved: 6.0%		
	Auxiliary Lane Width (4)		6-1	10'			11'		
	*New and Rehabilitated Bridges	Structural Capacity	~	SEE BRIDGE PROGRAM					
		Minimum Width	~						
	*Existing Bridges to Remain in Place	Structural Capacity	~						
		Minimum Width	~						
	Clear Zone		10-1	(5)					
	Side Slopes — Cut	Front Slope	6-3	1:3			1:4		
		Depth of Ditch	6-3	(6)					
		Back Slope	6-3	1:2 (7)					
	Side Slopes — Fill	0 - 15' Height	6-3	1:3			1:4		
		> 15' Height	6-3	1:2 (8)					
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (9)		4-1	20 mph	25 mph	30 mph	40 mph	45 mph	50 mph
				115'	155'	200'	305'	360'	425'
	Passing Sight Distance		4-1	710'	900'	1090'	1470'	1625'	1835'
	Decision Sight Distance (10)		4-1	300'	375'	450'	600'	675'	750'
	*Maximum Degree of Curve (e= 6.0%)		5-2	49° 15'	30° 45'	21°00'	11° 15'	8° 45'	6° 45'
	*Superelevation Rate		5-2	Table 5-6 (e_{max} = 6.0%)					
	*Horizontal Sight Distance		5-2	(11)					
	Maximum Profile Grades	Level	4-2	8%	7%	7%	7%	7%	6%
		Rolling	4-2	11%	10%	10%	9%	9%	8%
		Mountainous	4-2	16%	15%	14%	12%	12%	10%
	Minimum Profile Grades		4-2	Desirable: 0.25%			Minimum: 0%		
	*Minimum Vertical Clearance (12)	New and Replaced Overpassing Bridges	4-3	Desirable: 15'-6"			Minimum: 15'-0"		
		Existing Overpassing Bridges	4-3	14'-0"					

* Controlling design criteria (See Section 3-7).

GEOMETRIC DESIGN CRITERIA FOR RURAL LOCAL ROADS
(New Construction/Reconstruction)

Table 7-4

GEOMETRIC DESIGN CRITERIA FOR RURAL LOCAL ROADS
(New Construction/Reconstruction)

Footnotes to Table 7-4

1. Traffic Volumes. The AADT is determined for a future year, usually 20 years beyond the construction completion date.

2. Design Speed. Minimum values for design speed are presented. The designer should provide higher values where conditions allow. In addition, the design speed should equal or exceed the posted or regulatory speed limit of the completed facility.

3. Shoulder Width. The criteria refer to the paved shoulder width, if applicable, or to the graded shoulder width, if unpaved. The graded shoulder width is the distance between the edge of travel lane and the point of intersection of the shoulder slope and side slope. The following will also apply to shoulder widths:

   a. The minimum shoulder width is 4' if guardrail is used.
   b. In restricted locations (e.g., mountainous terrain), a shoulder width of 5'may be used.

   On rural local roads where curbs are provided, it is desirable to increase a proposed 4' or 6' shoulder by an additional 2'.

4. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 4' desirable and 2' minimum.

5. Clear Zone. Clear zone will vary according to design speed, traffic volume and side slope. See Section 10-1.

6. Depth of Ditch. A "V" ditch section should be used unless hydraulic capacity warrants the use of a trapezoidal ditch. Maintain the depth of ditch 1' below subgrade. If this criteria (1' below subgrade) determines the horizontal location of the ditch flow line, the calculated horizontal distance to the flow line will be rounded up to the next highest 6" increment.

7. Back Slope. For 4:1 front slopes, the Department's typical practice is to place the toe of the back slope outside of the clear zone. See the typical section figures in Section 6-5 and the clear zone discussion in Section 10-1. In rock cuts, the back slope may be as steep as 4:1. See rock cut detail in Figure 6-12.

8. Fill Slope (Height >15'). A 1.75:1 slope may be allowed to avoid significant right-of-way and/or environmental concerns.

9. Minimum Stopping Sight Distance. If practical, values in the columns may be adjusted for grades (see Table 4-1).

10. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

11. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and stopping sight distance (see Section 5-2).

12. Minimum Vertical Clearance. The vertical clearances apply to the local road passing under. For the 15-6" clearance, 6" is provided for future resurfacing. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the local road.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances

Design Element			Manual Section	2-Lane		Multi-lane (Divided/Undivided)	
				With Curb	Without Curb	With Curb	Without Curb
DESIGN CONTROLS	* Design Speed (1)		3-4	40-45 mph	30-45 mph	40-45 mph	45-50 mph
	Access Control		3-5	Entrance Control		Entrance Control	
	Level of Service		3-3	C		C	
	On-Street Parking		6-1	(2)		(2)	
CROSS SECTION ELEMENTS	*Lane Width		6-1	12'		12'	
	*Shoulder Width/Curb Offset	Right	6-1	8'	8'	Des: 10' Min: 2'	10'
		Left	6-1	N/A		Des: 4' Min: 1'	4'
	Cross Slope	*Travel Lane	6-1	2.0%		2.0%	
		Shoulder/Curb Offset (4)	6-1	4.0%		4.0%	
	Auxiliary Lane Width (5)		6-1	Desirable: 12' Minimum: 11'		Desirable: 12' Minimum: 11'	
	CTWLT Lane Width (6)		8-5	V>30: 14' V≤30: 12'		V>30: 14' V≤30: 12'	
	Parking Lane Width (7)		6-1	Desirable: 12' Minimum: 10'		Desirable: 12' Minimum: 10'	
	Sidewalk Width (8)		6-1	5' Minimum		5' Minimum	
	Median Width		6-2	N/A		N/A	
	*New and Rehabilitated Bridges	Structural Capacity	~	**SEE BRIDGE PROGRAM**		**SEE BRIDGE PROGRAM**	
		Minimum Width	~				
	*Existing Bridges to Remain in Place	Structural Capacity	~				
		Minimum Width	~				
	Clear Zone		10-1	(10)		(10)	
	Side Slopes		6-3	See Figure 6-11	See Table 7-2	See Figure 6-10	See Table 7-2
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (11)		4-1	40 mph	45 mph		50 mph
				305'	360'		425'
	Passing Sight Distance		4-1	1470'	1625'		1835'
	Decision Sight Distance (12)		4-1	825'	930'		1030'
	*Maximum Degree of Curve		5-2	11° 30' (e_{max} = 4.0%)	8° 45' (e_{max} = 6.0%)		6° 45' (e_{max} = 6.0%)
	*Superelevation Rate		5-2	Fig. 5-11 (e_{max} = 4.0%)	Table 5-6 (e_{max} = 6.0%)		Table 5-6 (e_{max} = 6.0%)
	*Horizontal Sight Distance		5-2	(13)			
	Maximum Profile Grades	Level	4-2	8%	6%		6%
		Rolling	4-2	9%	7%		7%
		Mountainous	4-2	11%	9%		9%
	Minimum Profile Grades		4-2	Curbed: Desirable~0.5%; Min.~0.25% Uncurbed: Desirable~0.25%; Min.~0%			
	*Minimum Vertical Clearance (14)	New and Replaced Overpassing Bridges	6-4	Desirable: 16'-6" Minimum: 16'-0"			
		Existing Overpassing Bridges	6-4	14'-0"			

* Controlling design criteria (See Section 3-7).

GEOMETRIC DESIGN CRITERIA FOR URBAN ARTERIAL ROADS/STREETS
(New Construction/Reconstruction)

Table 7-5

GEOMETRIC DESIGN CRITERIA FOR URBAN ARTERIALS
(New Construction/Reconstruction)

Footnotes to Table 7-5

1. Design Speed. A design speed of 30 mph may be used in restricted built-up areas. The design speed should equal or exceed the anticipated posted or regulatory speed limit of the completed facility.

2. On-Street Parking. The decision to provide on-street parking will be made on a case-by-case basis. See Section 6-1 for more information.

3. Travel Lane Cross Slope. On undivided multilane highways with curbs and where the shoulder width is less than 4’, both outside travel lanes will have a cross slope of 3.0% to provide more drainage.

4. Cross Slope (Curb Offset). For curb offsets (shoulder width less than 4’), the cross slope will be the same as the cross slope of the adjacent travel lane.

5. Auxiliary Lane Shoulders. Shoulder widths/curb offsets adjacent to auxiliary lanes should be 4’ desirable and 2’ minimum or the same as is adjacent to the travel lane, whichever is less.

6. CTWLT Lane Width. In industrial areas with large truck traffic turning frequently, the desirable CTWLT lane width is 16’for all design speeds.

7. Parking Lanes. Where the parking lane will be used as a travel lane during peak hours or may be converted to a travel lane in the future, the width should be 12’. Cross slopes for parking lanes should be 4.0%.

8. Sidewalk Width. Where roadside appurtenances are located within the sidewalk, the minimum width should be 7’. In built-up areas, the sidewalk is often paved between the curb and building line.

9. Median Widths (Between Edges of Travel Lanes). The following will apply:

   a. Widths for flush medians should range between 2’ and 6’.

   b. Widths for raised medians should range between 6’ and 18’. An 18’ width should be used where there are frequent left-turn lanes along the arterial to provide sufficient space for turn lanes.

   c. Widths for depressed medians should be determined by design requirements and field conditions.

   d. See Section 6-2 for more discussion.

10. Clear Zone. Clear zone will vary according to design speed, traffic volume, side slope and other factors. See Section 10-1.

11. Minimum Stopping Sight Distance. If practical, values in the columns may be adjusted for grades (see Table 4-1).

12. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

13. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and stopping sight distance (see Section 5-2).

14. Minimum Vertical Clearance. The vertical clearances apply to the arterial passing under. For the 16’-6” clearance, 6” is provided for future resurfacing. The minimum vertical clearance is 17’-6” for the arterial passing under a new pedestrian bridge or new sign truss. The clearance is 17’-0” for the arterial passing under an existing pedestrian bridge or existing sign truss. A 22’-6” (±6”) clearance, depending on actual site conditions, is required at railroad underpasses beneath the arterial.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

Design Element			Manual Section	With Curb		Without Curb
DESIGN CONTROLS	* Design Speed (1)		3-4	30-45 mph		
	Access Control		3-5	Entrance Control		
	Level of Service		3-3	C		
	On-Street Parking		6-1	(2)		
CROSS SECTION ELEMENTS	*Lane Width (3)		6-1	Desirable: 12'		Minimum: 11'
	*Shoulder Width/Curb Offset		6-1	Desirable: 8' Minimum: 6'		Desirable: 8' Minimum 6'
	Cross Slope	*Travel Lane	6-1	2.0%		
		Shoulder/Curb Offset (4)	6-1	4.0%		
	Auxiliary Lane Width (5)		6-1	Desirable: Same as lane width		Minimum: 10'
	Parking Lane Width		6-1	Desirable: 10'		Minimum: 7'
	Sidewalk Width (6)		6-1	5' Minimum		
	*New and Rehabilitated Bridges	Structural Capacity	~	SEE BRIDGE PROGRAM		SEE BRIDGE PROGRAM
		Minimum Width	~			
	*Existing Bridges to Remain in Place	Structural Capacity	~			
		Minimum Width	~			
	Clear Zone		10-1	(7)		
	Side Slopes		6-3	See Figure 6-11		See Table 7-4
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (8)		4-1	30 mph	35 mph	45 mph
				200'	250'	360'
	Passing Sight Distance		4-1	1090'	1280'	1625'
	Decision Sight Distance (9)		4-1	620'	720'	930'
	*Minimum Radius of Curve (e = 4.0%)		5-2	24° 45'	16° 30'	11° 30'
	*Superelevation Rate		5-2	Figure 5-11 (e_{max} = 4.0%)		
	*Horizontal Sight Distance		5-2	(10)		
	Maximum Profile Grades	Level	4-2	9%	9%	8%
		Rolling	4-2	11%	10%	9%
		Mountainous	4-2	12%	12%	11%
	Minimum Profile Grades		4-2	Curbed: Desirable~0.5%; Min.~0.25%		Uncurbed: Desirable~0.25%; Min.~0%
	*Minimum Vertical Clearance (11)	New and Replaced Overpassing Bridges	6-4	Desirable: 15'-6"		Minimum: 15'-0"
		Existing Overpassing Bridges	6-4	14'-0"		

* Controlling design criteria (See Section 3-7).

GEOMETRIC DESIGN CRITERIA FOR URBAN COLLECTOR ROADS/STREETS
(New Construction/Reconstruction)

Table 7-6

GEOMETRIC DESIGN CRITERIA FOR URBAN COLLECTOR ROADS/STREETS
(New Construction/Reconstruction)

Footnotes to Table 7-6

1. Design Speed. The design speed should equal or exceed the anticipated posted or regulatory speed limit of the completed facility.

2. On-Street Parking. The decision to provide on-street parking will be made on a case-by-case basis. See Section 6-1 for more information.

3. Lane Width. In industrial areas, lanes should be 12' wide. In residential areas in restricted locations, lanes may be 10' wide.

4. Cross Slope (Curb Offset). For curb offsets (shoulder width less than 4'), the cross slope will be the same as the cross slope of the travel lane.

5. Auxiliary Lane Shoulders. Shoulder widths/curb offsets adjacent to auxiliary lanes should be 4' desirable and 2' minimum or the same as is adjacent to the travel lane, whichever is less.

6. Sidewalk Width. Where roadside appurtenances are located within the sidewalk, the minimum width should be 7'. In built-up areas, the sidewalk is often paved between the curb and building line.

7. Clear Zone. Clear zone will vary according to design speed, traffic volume, side slope and other factors. See Section 10-1.

8. Minimum Stopping Sight Distance. If practical, values in the columns may be adjusted for grades (see Table 4-1).

9. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

10. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and stopping sight distance (see Section 5-2).

11. Minimum Vertical Clearance. The vertical clearances apply to the collector passing under. For the 15'-6" clearance, 6" is provided for future resurfacing. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the collector.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

<table>
<tr><th colspan="3">Design Element</th><th>Manual Section</th><th colspan="3">With Curb</th><th colspan="2">Without Curb</th></tr>
<tr><td rowspan="4">DESIGN CONTROLS</td><td colspan="2">* Design Speed (1)</td><td>3-4</td><td colspan="5">20-30 mph</td></tr>
<tr><td colspan="2">Access Control</td><td>3-5</td><td colspan="5">Entrance Control</td></tr>
<tr><td colspan="2">Level of Service</td><td>3-3</td><td colspan="5">C</td></tr>
<tr><td colspan="2">On-Street Parking</td><td>6-1</td><td colspan="5">(2)</td></tr>
<tr><td rowspan="13">CROSS SECTION ELEMENTS</td><td colspan="2">*Lane Width</td><td>6-1</td><td colspan="3">Desirable: 11'</td><td colspan="2">Minimum: 10'</td></tr>
<tr><td colspan="2">*Shoulder Width/Curb Offset</td><td>6-1</td><td colspan="3">2'-6'</td><td colspan="2">4'-6'</td></tr>
<tr><td rowspan="2">Cross Slope</td><td>*Travel Lane</td><td>6-1</td><td colspan="5">2.0%</td></tr>
<tr><td>Shoulder/Curb Offset (3)</td><td>6-1</td><td colspan="5">4.0%</td></tr>
<tr><td colspan="2">Auxiliary Lane Width (4)</td><td>6-1</td><td colspan="3">Desirable: 11'</td><td colspan="2">Minimum: 10'</td></tr>
<tr><td colspan="2">Parking Lane Width</td><td>6-1</td><td colspan="3">Desirable: 9'</td><td colspan="2">Minimum: 7'</td></tr>
<tr><td colspan="2">Sidewalk Width (5)</td><td>6-1</td><td colspan="5">5' Typical</td></tr>
<tr><td rowspan="2">*New and Rehabilitated Bridges</td><td>Structural Capacity</td><td>~</td><td colspan="3" rowspan="4">SEE BRIDGE PROGRAM</td><td colspan="2" rowspan="4">SEE BRIDGE PROGRAM</td></tr>
<tr><td>Minimum Width</td><td>~</td></tr>
<tr><td rowspan="2">*Existing Bridges to Remain in Place</td><td>Structural Capacity</td><td>~</td></tr>
<tr><td>Minimum Width</td><td>~</td></tr>
<tr><td colspan="2">Clear Zone</td><td>10-1</td><td colspan="5">(6)</td></tr>
<tr><td colspan="2">Side Slopes</td><td>6-3</td><td colspan="3">See Figure 6-11</td><td colspan="2">See Table 7-4</td></tr>
<tr><td rowspan="12">ALIGNMENT ELEMENTS</td><td colspan="2" rowspan="2">*Minimum Stopping Sight Distance (7)</td><td rowspan="2">4-1</td><td>20 mph</td><td colspan="3">25 mph</td><td>30 mph</td></tr>
<tr><td>115'</td><td colspan="3">155'</td><td>200'</td></tr>
<tr><td colspan="2">Passing Sight Distance</td><td>4-1</td><td>710'</td><td colspan="3">900'</td><td>1090'</td></tr>
<tr><td colspan="2">Decision Sight Distance (8)</td><td>4-1</td><td>420'</td><td colspan="3">520'</td><td>620'</td></tr>
<tr><td colspan="2">*Maximum Degree of Curve (e = 4.0%)</td><td>5-2</td><td>72° 45'</td><td colspan="3">40° 00</td><td>24° 45'</td></tr>
<tr><td colspan="2">*Superelevation Rate</td><td>5-2</td><td colspan="5">Figure 5-12 (e_{max} = 4.0%)</td></tr>
<tr><td colspan="2">*Horizontal Sight Distance</td><td>5-2</td><td colspan="5">(9)</td></tr>
<tr><td rowspan="2">Maximum Profile Grades</td><td>Residential</td><td>4-2</td><td colspan="5">10%</td></tr>
<tr><td>Commercial/Industrial</td><td>4-2</td><td colspan="5">5%</td></tr>
<tr><td colspan="2">Minimum Profile Grades</td><td>4-2</td><td colspan="5">Curbed: Desirable~0.5%; Min.~0.25% Uncurbed: Desirable~0.25%; Min.~0%</td></tr>
<tr><td rowspan="2">*Minimum Vertical Clearance (10)</td><td>New and Replaced Overpassing Bridges</td><td>6-4</td><td colspan="3">Desirable: 15'-6"</td><td colspan="2">Minimum: 15'-0"</td></tr>
<tr><td>Existing Overpassing Bridges</td><td>6-4</td><td colspan="5">14'-0"</td></tr>
</table>

* Controlling design criteria (See Section 3-7).

GEOMETRIC DESIGN CRITERIA FOR URBAN LOCAL ROADS/STREETS
(New Construction/Reconstruction)

Table 7-7

GEOMETRIC DESIGN CRITERIA FOR URBAN LOCAL ROADS/STREETS
(New Construction/Reconstruction)

Footnotes to Table 7-7

1. Design Speed. The design speed should equal or exceed the anticipated posted or regulatory speed limit of the completed facility.

2. On-Street Parking. The decision to provide on-street parking will be made on a case-by-case basis. See Section 6-1 for more information.

3. Cross Slope (Curb Offsets). For curb offsets (shoulder width less than 4'), the cross slope will be the same as the cross slope of the travel lane.

4. Auxiliary Lane Shoulders. Shoulder widths/curb offsets adjacent to auxiliary lanes should be 4' desirable and 2' minimum or the same as is adjacent to the travel lane, whichever is less.

5. Sidewalk Width. Where roadside appurtenances are located within the sidewalk, the minimum width should be 7'. In built-up areas, the sidewalk is often paved between the curb and building line.

6. Clear Zone. Clear zone will vary according to design speed, traffic volume, side slope and other factors. See Section 10-1.

7. Minimum Stopping Sight Distance. If practical, values in the columns may be adjusted for grades (see Table 4-1).

8. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

9. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and stopping sight distance (see Section 5-2).

10. Minimum Vertical Clearance. The vertical clearances apply to the local road/street passing under. For the 15'-6" clearance, 6" is provided for future resurfacing. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the local road/street.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances

CHAPTER EIGHT

INTERSECTIONS AT-GRADE

Volume I

\- Highway Design Guide –

National Standards

December 2004

Chapter Eight

TABLE OF CONTENTS

Page

TABLE OF CONTENTS
(Continued)

Chapter Eight

INTERSECTIONS AT-GRADE

8-1 INTERSECTION SIGHT DISTANCE (ISD)

8-1.01 No Traffic Control

Intersections between low-volume and low-speed roads/streets may have no traffic control. At these intersections, sufficient corner sight distance should be available to allow approaching vehicles to adjust speed to avoid a collision. Figure 8-1 provides the ISD criteria for intersections with no traffic control.

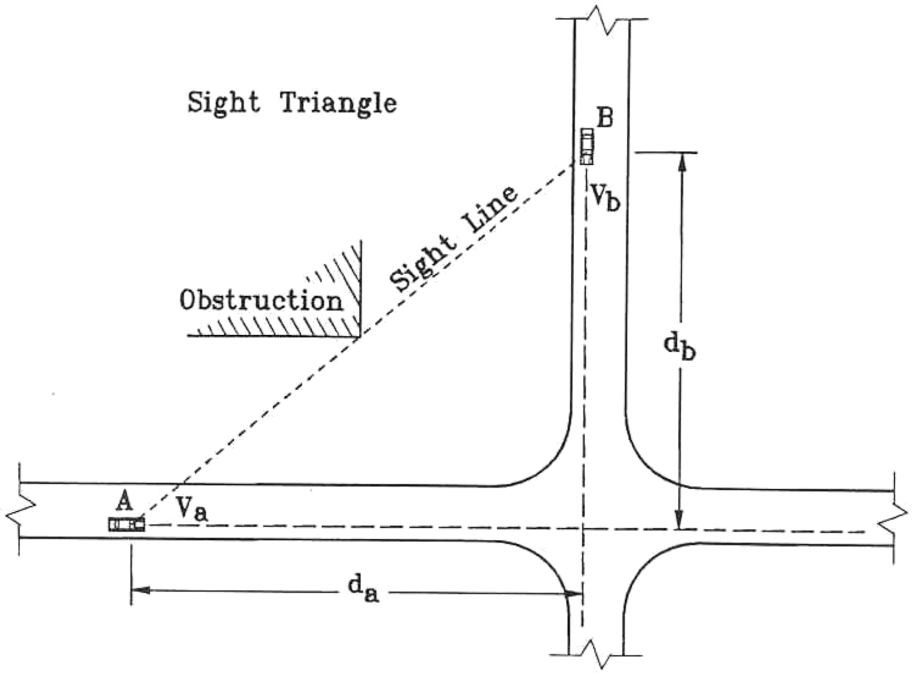
8-1.02 Yield Control

Yield control may exist, for example, at a freeway ramp terminal where the ramp traffic is provided a free-flowing right turn onto the minor road. At these locations, the driver on the freeway ramp needs sufficient sight distance to slow down to approximately 15 mph on the turning roadway and to determine if he/she should stop or proceed onto the minor road without a stop. The driver on the minor road needs sufficient sight distance to avoid a collision with the merging vehicle from the freeway ramp. These two objectives will determine the legs of the triangle to provide corner sight distance. Figure 8-2 illustrates sight distance at yield control locations and provides the criteria for application.

If insufficient sight distance is available for the operational characteristics of yield control, it may be appropriate to convert the yield into a stop control. The Traffic Engineering Division will make the final decision.

8-1.03 Stop Control

Figure 8-3 illustrates the application of the ISD criteria for stop-controlled intersections. In addition to the criteria in the Figure, the designer should consider the following:



Design Speed (mph)	15	20	25	30	40	45	50	55	60
Sight Distance (ft)	70	90	115	140	195	220	245	285	325

Example

Given: No traffic control at intersection.

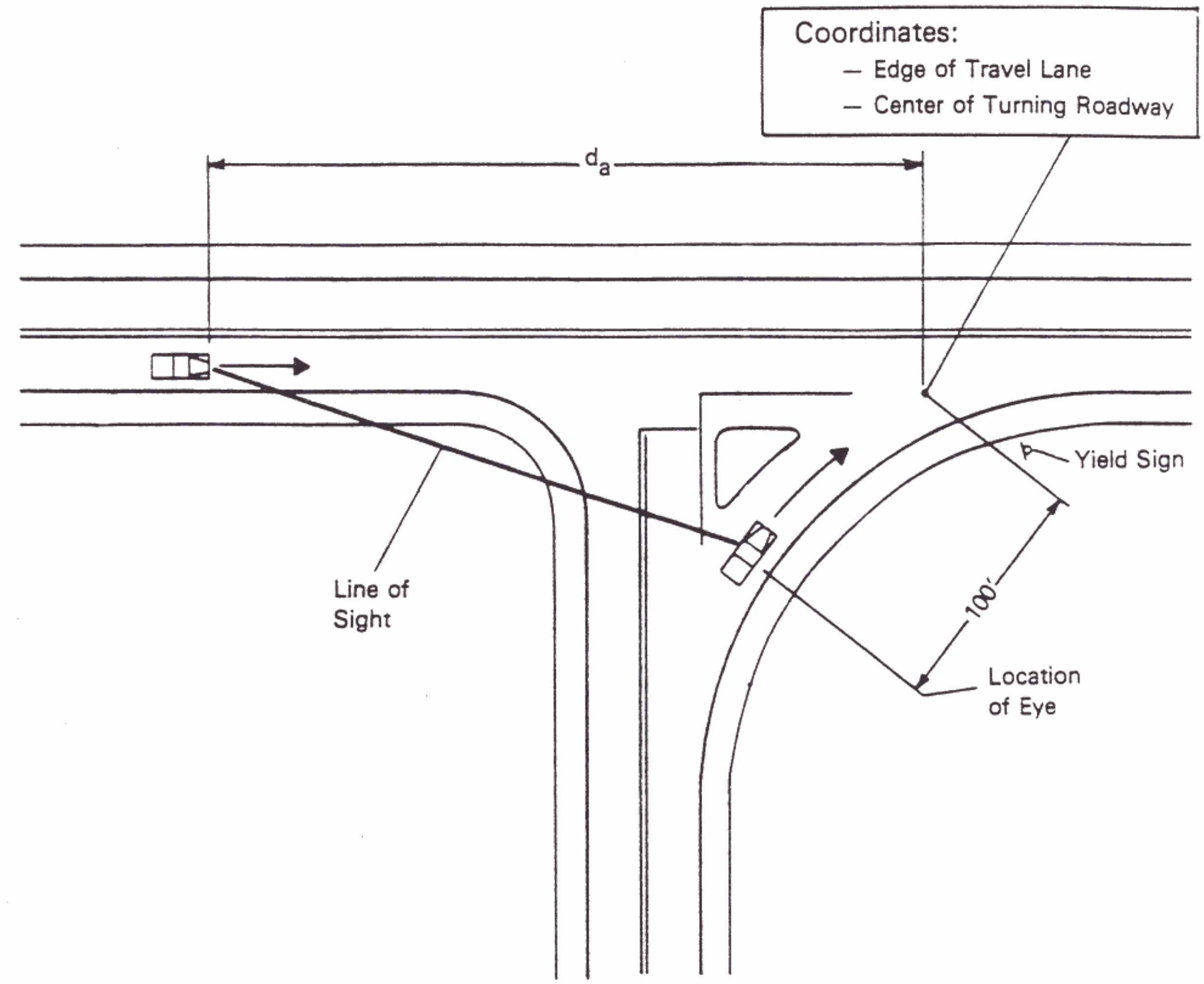
Design speed – 40 mph (Highway A)
30 mph (Highway B)

Problem: Determine legs of sight triangle.

Solution: From above table – d_a = 195 ft
d_b = 140 ft

INTERSECTION SIGHT DISTANCE
(No Traffic Control)

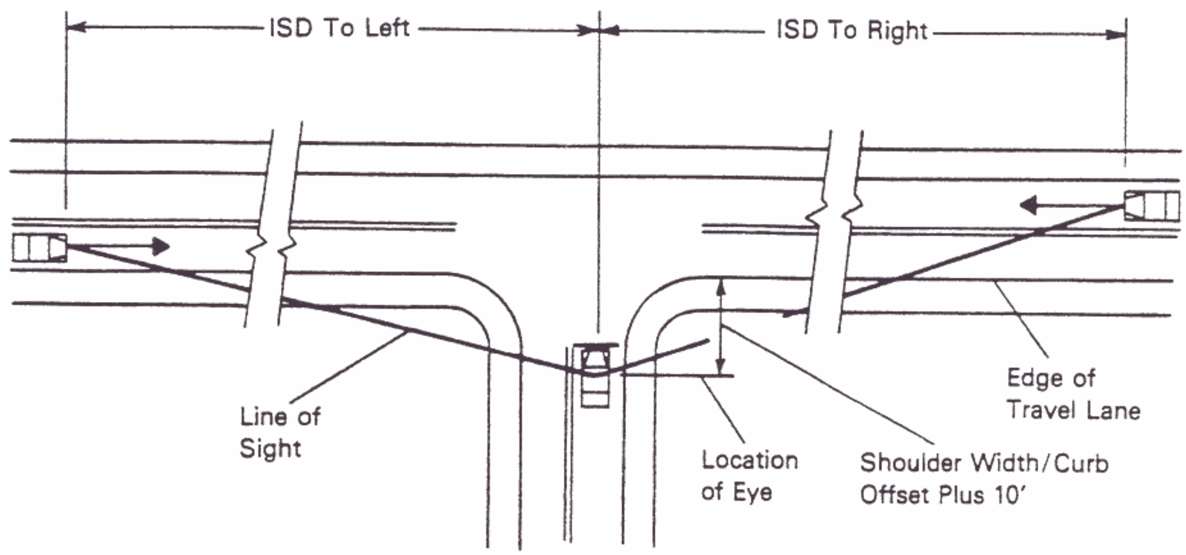
Figure 8-1



Design Speed (mph)	30	40	45	50	55	60
Sight Distance (d_a) (ft)	140	195	220	245	285	325

INTERSECTION SIGHT DISTANCE
(Yield Control)

Figure 8-2



Design Speed (mph)	25	30	35	45	50	55	60	65
Sight Distance (ft)	280	335	390	500	555	610	665	720

INTERSECTION SIGHT DISTANCE
(Stop Control)

Figure 8-3

1. Traffic Volumes. The ISD criteria are independent of mainline and turning volumes. At lower volume intersections, it may not be practical to meet these criteria.

2. Truck Volumes. The ISD criteria are based on operational characteristics of passenger cars. At intersections with higher truck volumes, it may be warranted to provide greater ISD values.

3. Multilane Facilities. The ISD model assumes a two-lane facility. On multilane facilities which do not have a median wide enough to store a stopped vehicle, the criteria in Figure 8-3 will also apply. On multilane facilities with a median wide enough to store a stopped vehicle, the designer should evaluate the ISD requirements in two steps:

    a. With the vehicle stopped on the side road, the ISD will be checked to the left on the mainline.

    b. With the vehicle stopped in the median, the ISD will be checked to the right on the mainline.

4. Height of Eye/Object. The height of eye is 3.5 feet, and the height of object (an approaching passenger car) is 3.5 feet.

8-1.04 Signal Control

Where right-turn-on-red is allowed, the designer should check to determine if the ISD criteria in Figure 8-3 (to the left) is available for right-turning vehicles. If not, this may be justification for prohibiting the maneuver at the intersection. The designer should notify the Traffic Engineering Division or the responsible municipality of the situation.

8-2 TURNING RADII DESIGN

Each intersection will be designed according to each of the parameters described in the following sections.

8-2.01 Design Vehicle Selection

Figure 8-4 through 8-9 provide the turning paths for the typical design vehicles (WB-62, WB-50, WB-40, BUS, SU and P, WB-67). The WB-67 will typically be the selected design vehicle for determining the appropriate turning radii design. In urban areas, use the largest turning radius that can be practically used at the intersection.

Pursuant to the requirements of the 1982 Surface Transportation Assistance Act (STAA), the State of Maine has established its federally designated routes for use by the WB-67 design vehicle. The State has also established its application for the "reasonable access" provision of the 1982 STAA. The Federally designated routes are:

1. Maine Interstate System,

2. Scarborough Connector from I-295 in South Portland to U.S. Route 1 in South Portland,

3. South Portland Spur from I-95 in South Portland to U.S. Route 1 in South Portland,

4. Maine Turnpike from I-95 in Portland to I-95 at West Gardner,

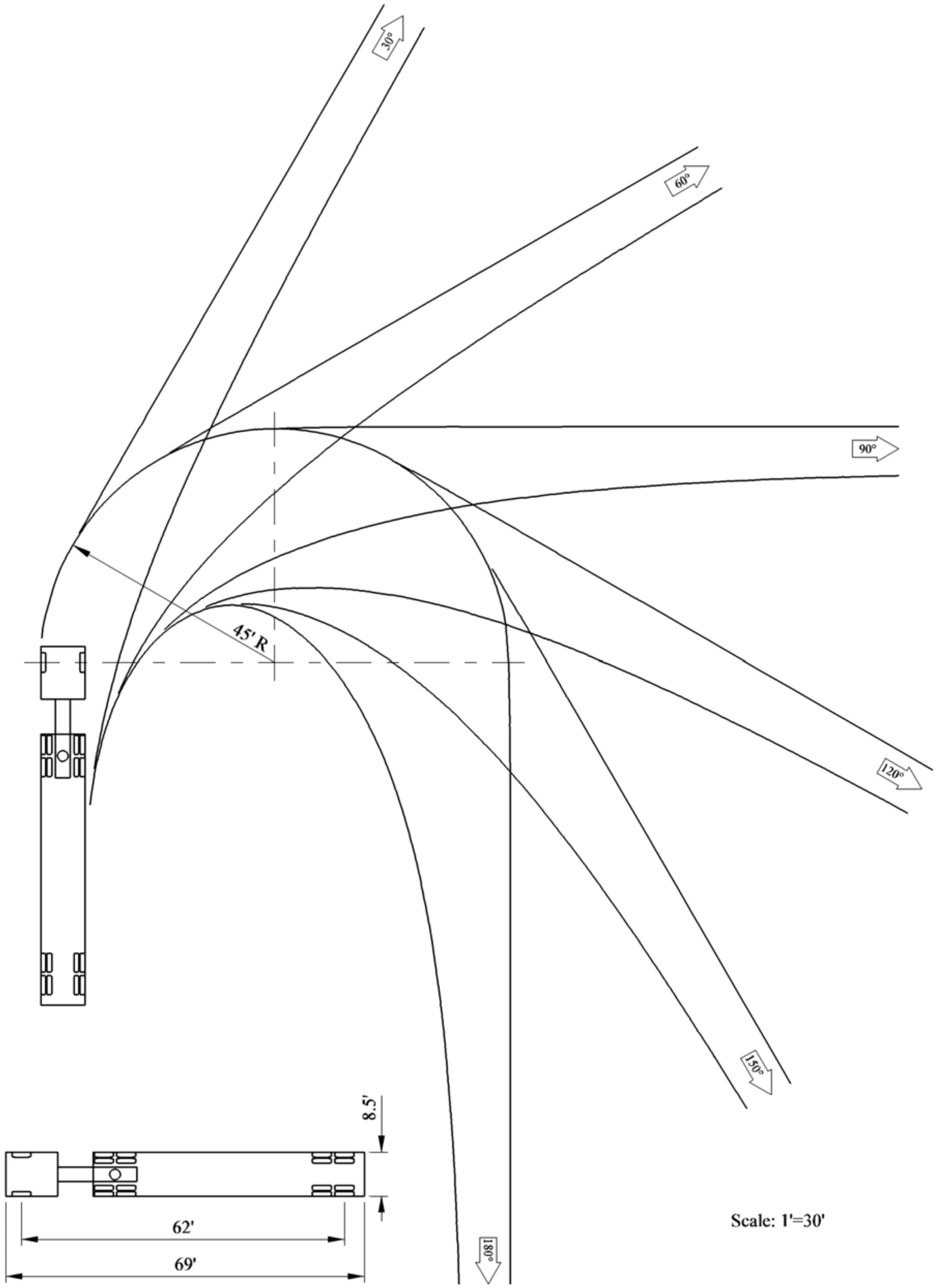
5. U.S. Route 1 from I-95 at Brunswick to the Congress Street/U.S. Route 1 interchange in Bath, and

6. U.S. Route 1 from I-95 at Houlton to the Canadian border at Fort Kent.

For the purpose of reasonable access, the WB-67 has general permission to operate on the entire State Aid and State Highway System.

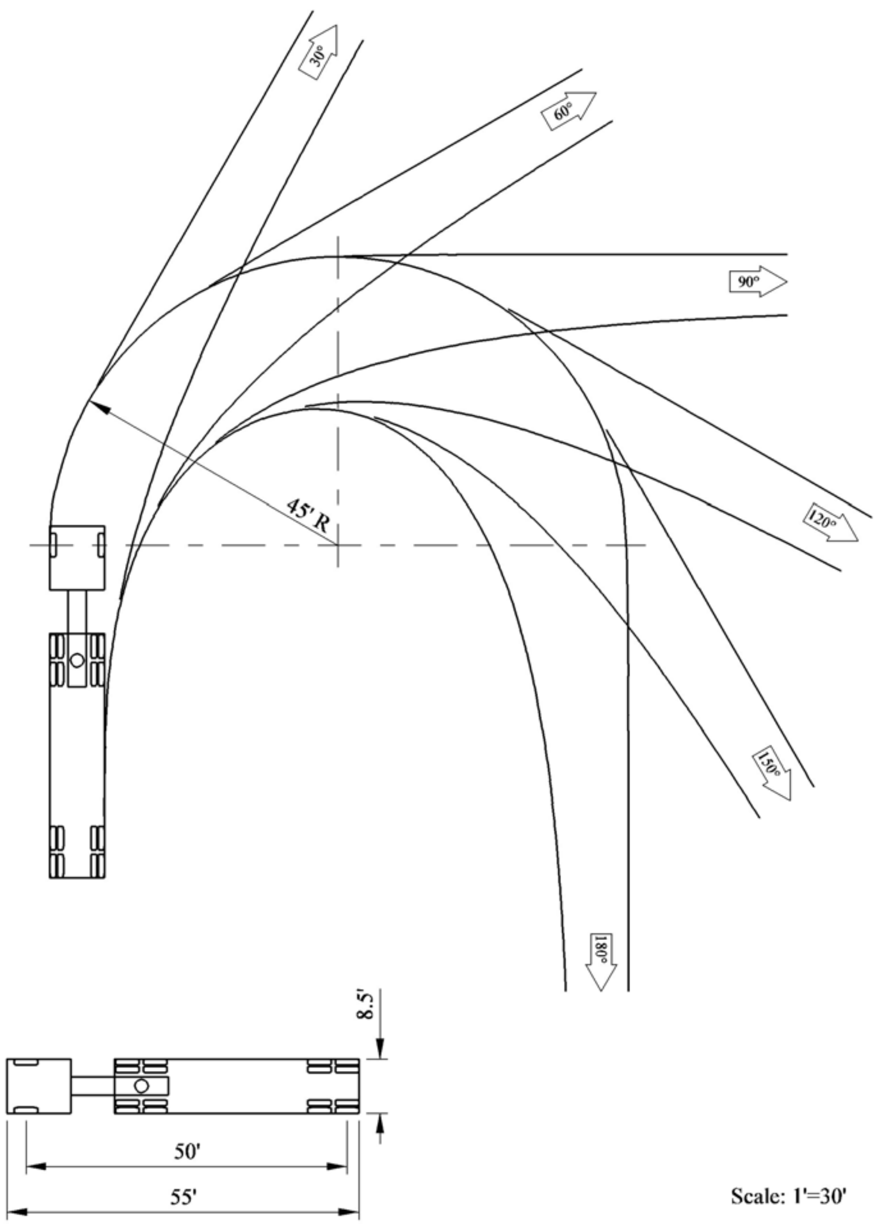
8-2.02 Inside Clearance

The design vehicle will be assumed to make the right turn while the inner wheels maintain approximately a 2-foot clearance from the pavement edge or curb line throughout the turn.



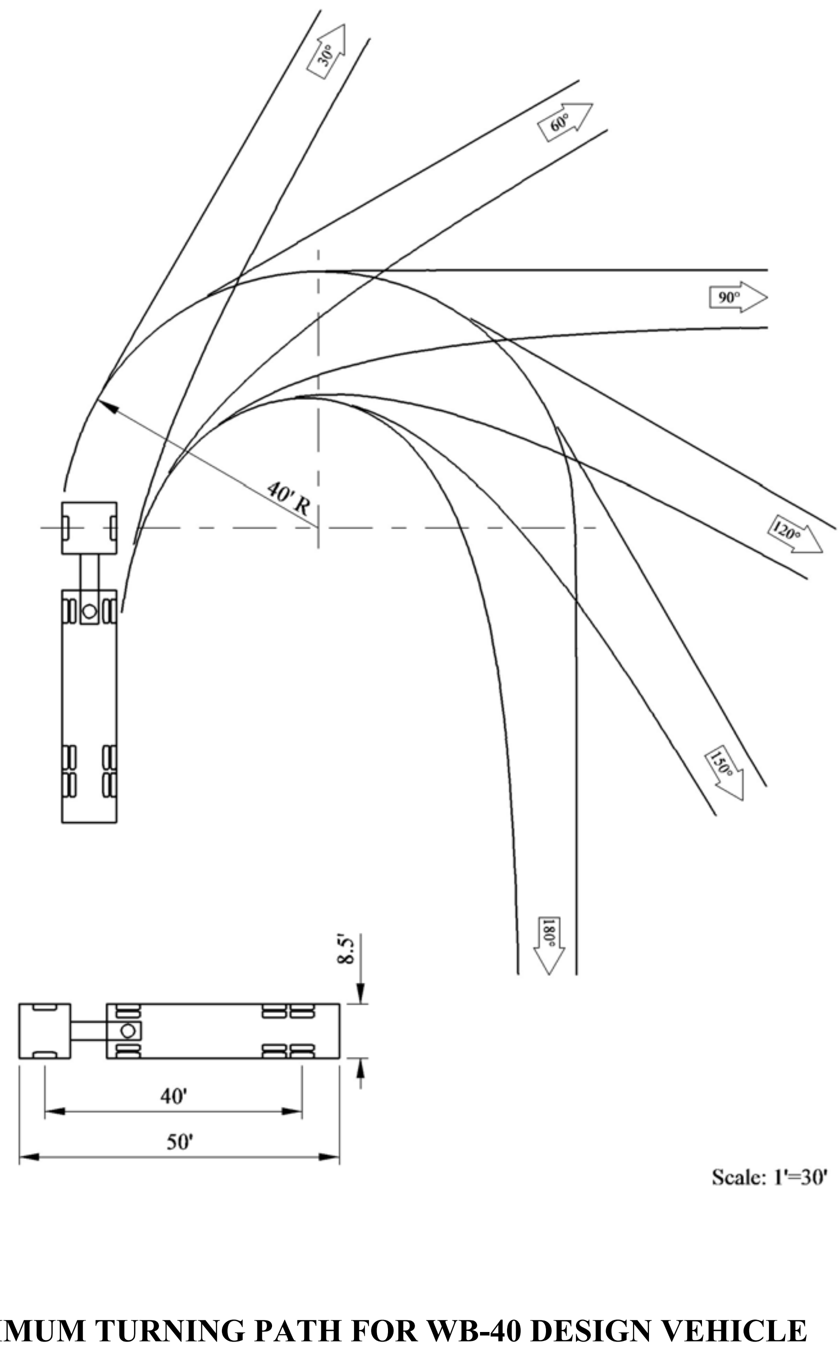
MINIMUM TURNING PATH FOR WB-62 DESIGN VEHICLE

Figure 8-4



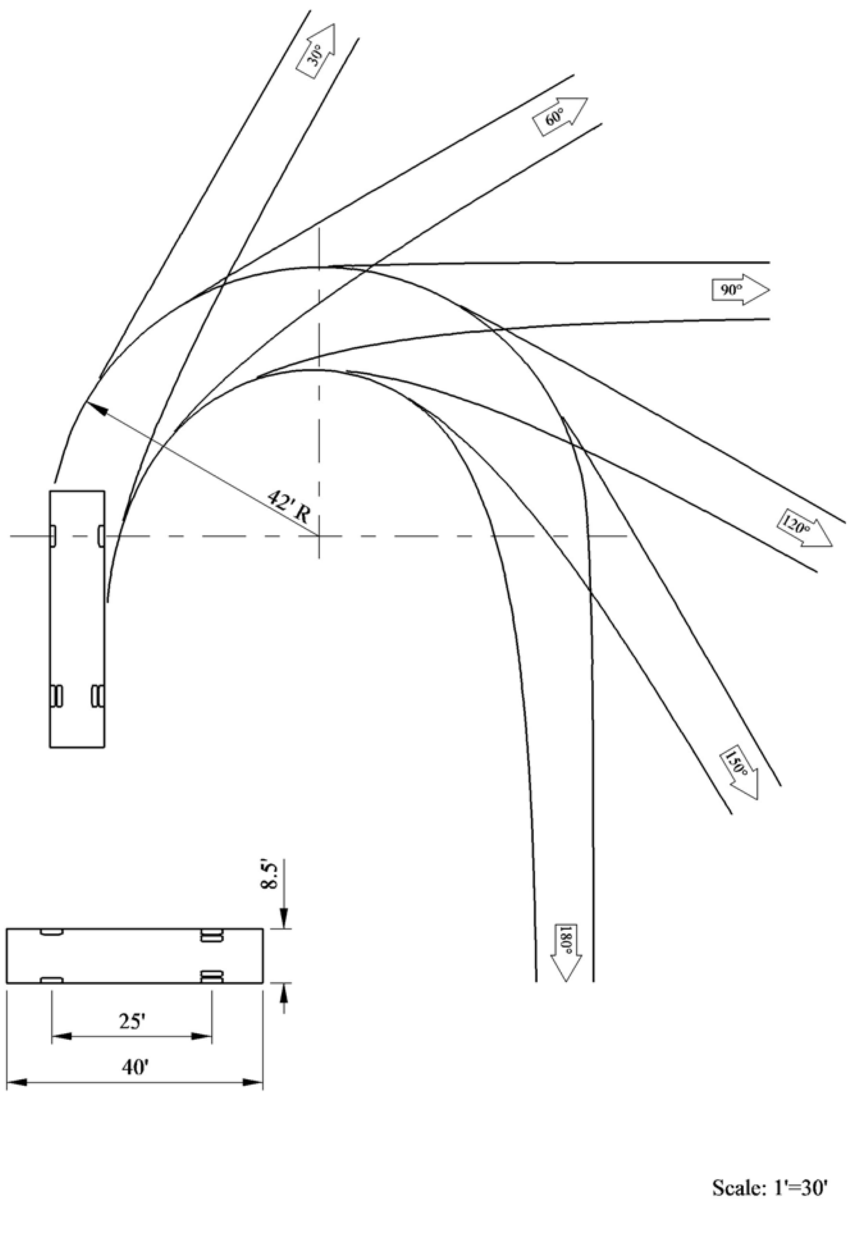
MINIMUM TURNING PATH FOR WB-50 DESIGN VEHICLE

Figure 8-5



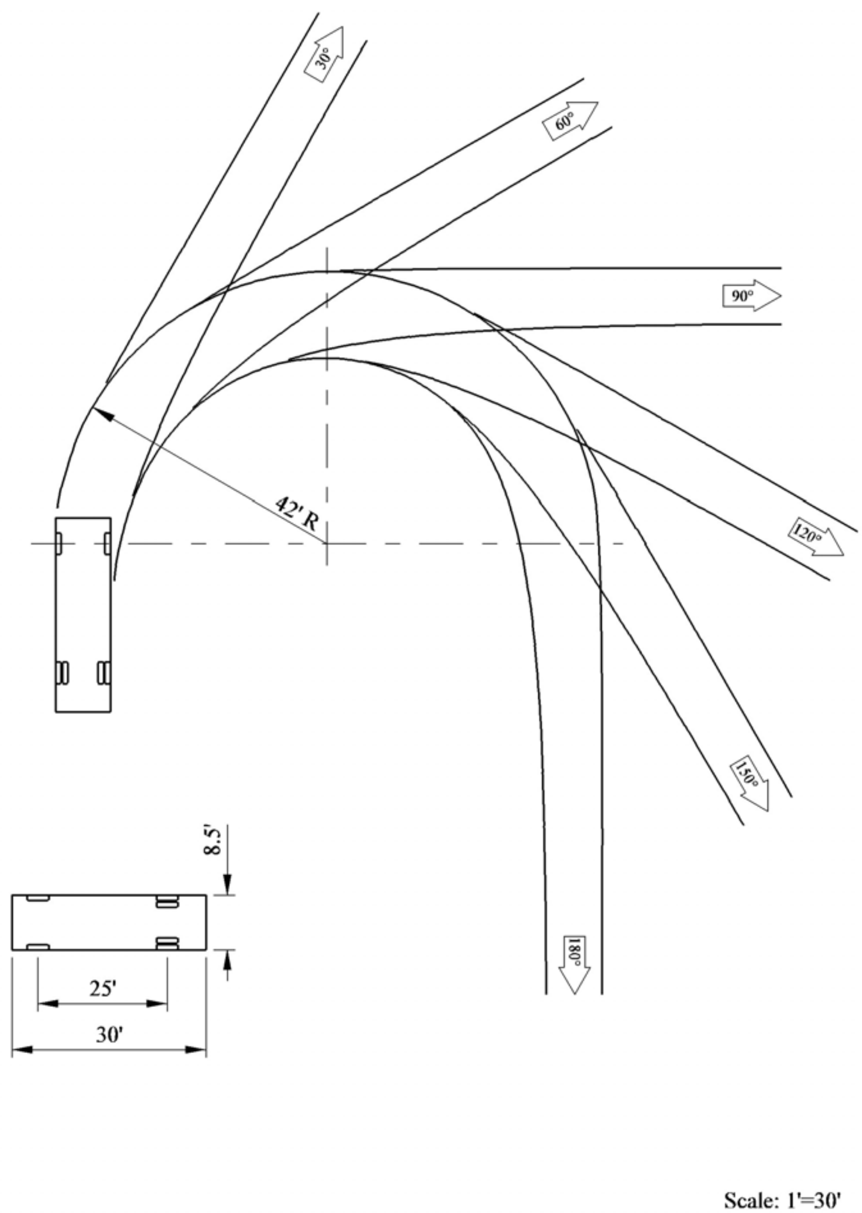
MINIMUM TURNING PATH FOR WB-40 DESIGN VEHICLE

Figure 8-6



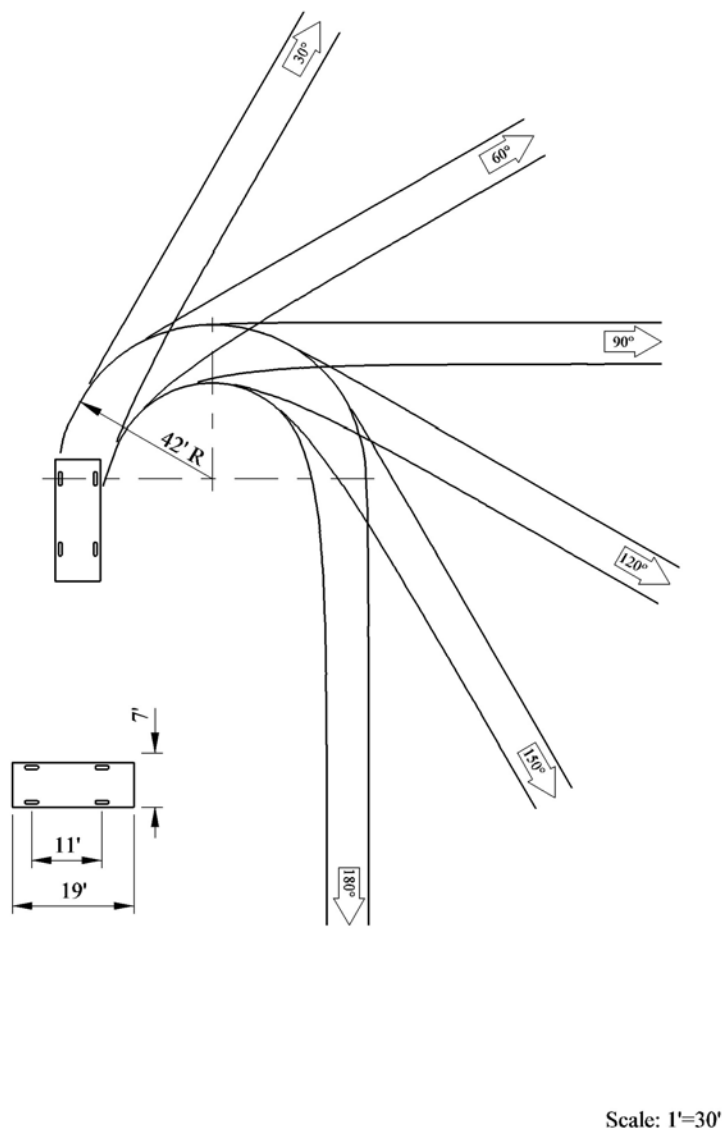
MINIMUM TURNING PATH FOR BUS DESIGN VEHICLE

Figure 8-7



MINIMUM TURNING PATH FOR SU DESIGN VEHICLE

Figure 8-8



MINIMUM TURNING PATH FOR P DESIGN VEHICLE

Figure 8-9

8-2.03 Encroachment

The following will apply to vehicular encroachment into other lanes:

1. ***Initial Position***. Before the turn is made, the design vehicle (WB-67) is assumed to be in the lane which will require the most restrictive right-turn maneuver.

2. ***Road From Which Turn Made***. The turning vehicle (WB-67) will not encroach onto the adjacent lane on the road from which the turn is made.

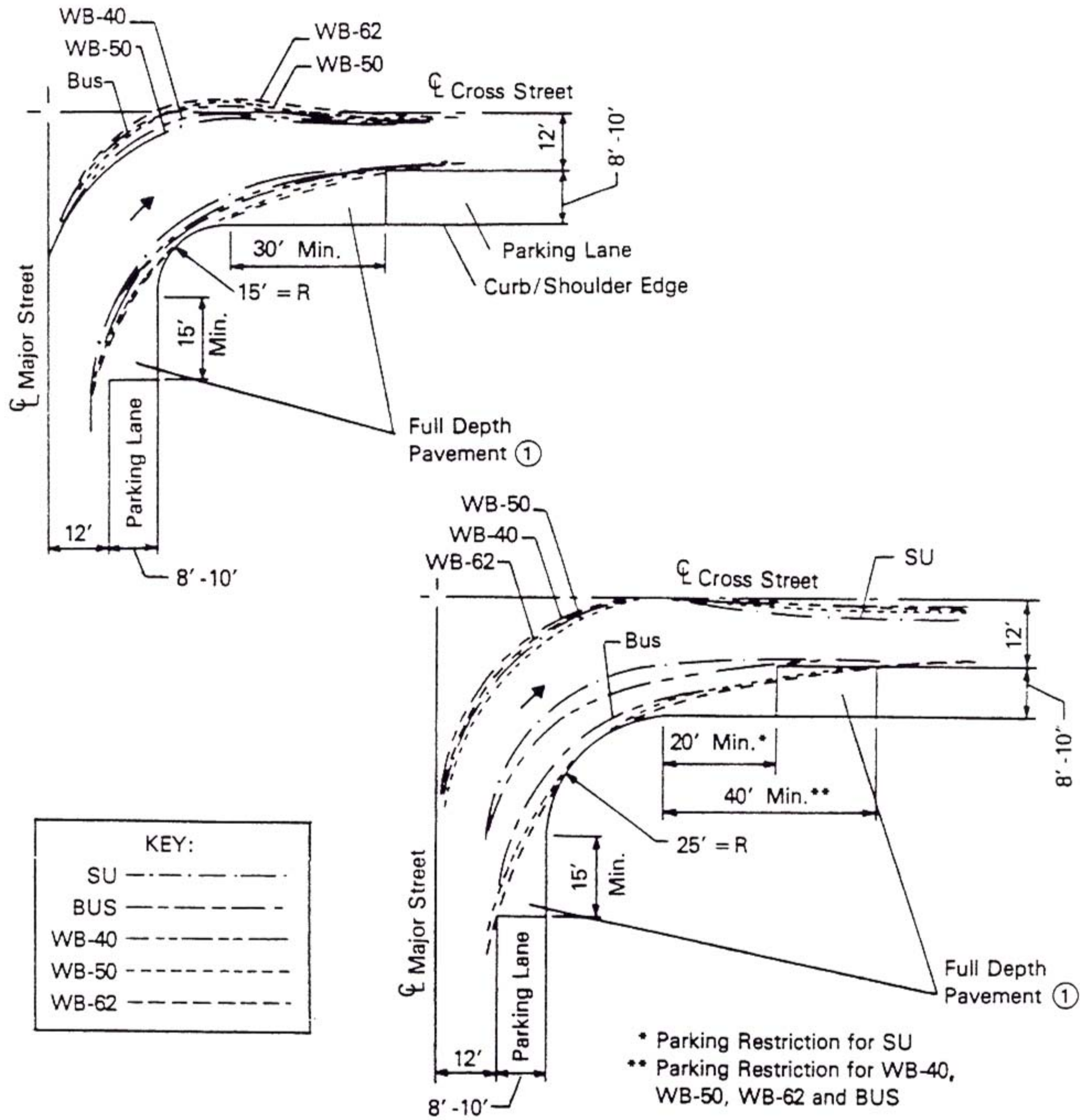
3. ***Road Onto Which Turn Made***. For turns onto arterial and collector facilities, the turning vehicle (WB-67) cannot encroach into opposing lanes of traffic. If there are two or more lanes of traffic moving in the same direction, it is acceptable for the turning vehicle to occupy both travel lanes. However, if practical, the turning vehicle will be able to make the turn while remaining entirely in the right through lane.

   For turns onto local facilities, the WB-67 should physically be able to make the turn within the available paved area without impacting curbs, parked vehicles, appurtenances (e.g., utility poles) or any other obstacles. An exception to this will be freeway ramp intersections with local facilities. The WB-67 should be able to make the turn from the freeway ramp to the local facility without encroaching into opposing lanes of traffic.

4. ***Other Factors***. When determining the geometric design elements of the intersection (e.g., lane widths), the designer should evaluate many factors. These include turning volumes, through volumes, typical speeds approaching the intersections and the type of traffic control at the intersection. The designer must also consider the construction and right-of-way impacts for meeting the encroachment recommendations. For example, if these impacts are significant and if through and/or turning volumes are relatively low, the designer may decide to accept an encroachment for the design vehicle (WB-67) which exceeds the recommendations in Numbers 2 & 3 above.

8-2.04 Parking Lanes/Shoulders

At many intersections, parking lanes and/or shoulders will be available on one or both approach legs, and this additional roadway width may be carried through the intersection. This will greatly ease the turning problems for large vehicles at intersections with small curb radii. Figure 8-10 illustrates the turning paths of several design vehicles where radii are 15 feet or 25 feet and



① Full-depth pavement will begin where encroachment onto shoulder begins and will continue until encroachment ends.

② Dimensions shown are for illustrative purposes. As discussed in Section 8-2, actual dimensions will be determined case-by-case based on field conditions.

EFFECTS OF PARKING LANES/SHOULDERS ON VEHICULAR TURNING PATHS

Figure 8-10

where 8-foot to 10-foot parking lanes are provided. The presence of a shoulder 8-foot to 10-foot in width will have the same impact as a parking lane.

The figure also illustrates the necessary distance to restrict parking before the P.C. (15 feet) and after the P.T. (20 to 40 feet) on the cross street. The designer will, of course, need to check the proposed design with the applicable turning template and encroachment criteria. The designer should not consider the beneficial effects of a parking lane if the lane will be used for through traffic part of the day or if parking will likely be prohibited in the future.

Figure 8-10 indicates approximately where the parking lane or shoulder will have a full-depth pavement structure. This treatment is critical to avoid pavement deterioration from trucks turning at the intersection.

8-2.05 Pedestrians

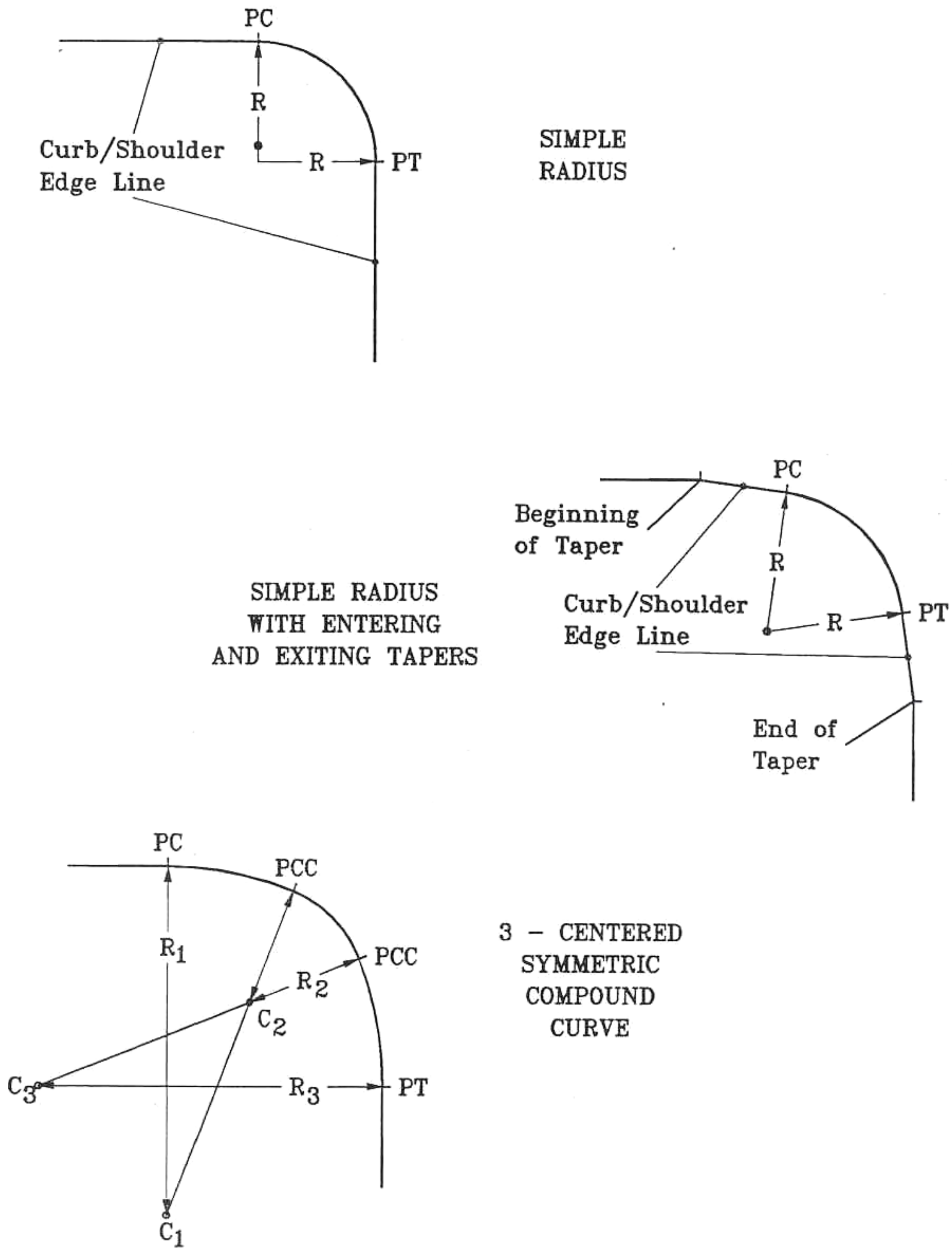
The greater the turning radius or the number of lanes, the farther pedestrians must walk in the roadway. This is especially important to handicapped individuals. Therefore, the designer should consider this when determining the edge of pavement or curb line design. This may lead to, for example, the decision to use a simple curve with taper offsets or a 3-centered compound curve (see Section 8-2.06) or a turning roadway (see Section 8-3) to provide a pedestrian refuge.

8-2.06 Types of Turning Designs

Once the designer has determined the basic turning parameters (e.g., design vehicle, encroachment, inside clearance), it is necessary to select a type of turning design for the curb return which will meet these criteria and will fit the intersection constraints. The design may be one of the following basic types:

1. simple radius,
2. simple radius with entering and exiting tapers, or
3. 3-centered symmetrical compound curve.

Figure 8-11 illustrates all three basic turning designs. Each design type has its advantages and disadvantages. The simple radius is the easiest to design and construct and, therefore, it is the most common. The 3-centered symmetrical compound curve arrangement provides the "best" fit to the transitional turning paths of vehicles. However, the designer should also consider the



TYPES OF INTERSECTION TURNING DESIGNS

Figure 8-11

benefits of the simple radius with an entering and exiting taper. Some advantages of the simple radius/taper or 3-centered curve designs (as compared to the simple radius design) include:

1. To accommodate a specific vehicle with no encroachment, a simple radius requires greater intersection pavement area than a radius with tapers or 3-centered curve. Another benefit is the reduced right-of-way impact in the intersection corners. For large vehicles, a simple radius is often an unreasonable design, unless a channelized island is used.

2. A simple radius results in greater distances for pedestrians to cross than a radius with tapers or a 3-centered curve.

3. For angles of turn greater than 90°, a radius with tapers or a 3-centered curve is a better design than a simple radius, primarily because less intersection area is required.

4. The simple radius with tapers provides approximately the same transitional benefits as the compound curvature arrangements, but it is easier to design, survey and construct.

8-2.07 Summary

Figure 8-12 illustrates the many factors which should be evaluated in determining the proper design for right turns at intersections. In summary, the following procedure applies:

1. Select the design vehicle (typically the WB-67).

2. Determine the acceptable inside clearance (Section 8-2.02).

3. Determine the acceptable encroachment (Section 8-2.03).

4. Consider the benefits of any parking lanes or shoulders (Section 8-2.04).

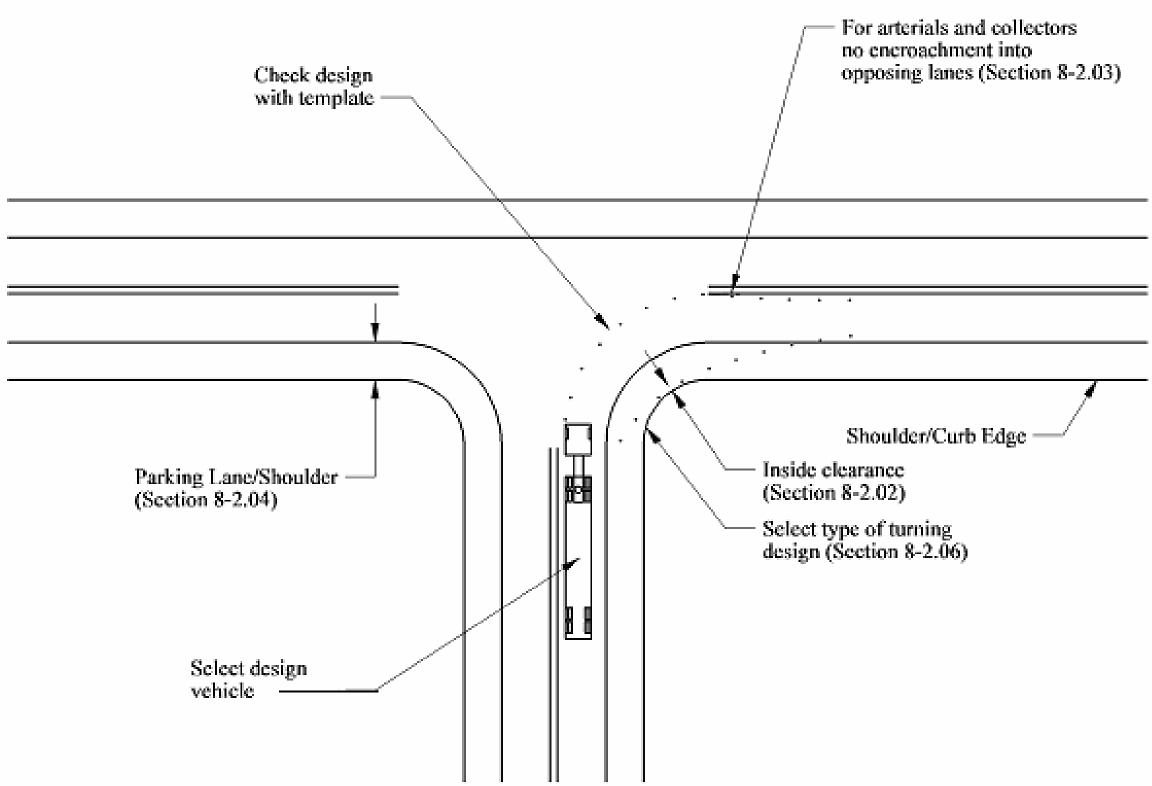
5. Consider impacts on pedestrians (Section 8-2.05).

6. Select the type of turning treatment (Section 8-2.06):

   a. simple radius,
   b. simple radius with entering and exiting tapers, or
   c. 3-centered compound curve.

7. Check all proposed designs with the applicable vehicular turning template.

8. Revise design as necessary to accommodate the right-turning vehicle <u>or</u> determine that it is not practical to meet this design because of adverse impacts.



TURNING RADII DESIGN

Figure 8-12

8-3 TURNING ROADWAYS

Turning roadways are channelized areas (separated by an island) which allow a moderate-speed, free-flowing right turn away from the intersection area. The designer should consider using turning roadways when:

1. it is desirable to allow right turns at speeds of 15 mph or more;

2. the angle of turn is greater than 90°;

3. the volume of right turns is high, the turning movement is from a high-volume road or it is desirable to remove right turns away from a signal;

4. it is desirable to reduce the intersection paved area. As a guide, if an island with a turning roadway will be at least 75 square feet (urban) or 100 square feet (rural), then a turning roadway should be considered; and/or

5. pedestrian volumes are high and a pedestrian refuge is a desirable feature.

Figure 8-13 illustrates a possible design for a turning roadway at an urban intersection. This figure presents a turning roadway with a 3-centered compound curve, although a simple curve is often acceptable. Table 8-1 presents the minimum radii, superelevation and width for various design speeds. The following sections discuss the design details of a turning roadway.

8-3.01 Design Speed

The designer must select a controlling design speed for the turning roadway. Typically, the design speed will be in the range of 15-20 mph. It is desirable, however, that the design speed on the turning roadway be within 10 mph of the design speed on the approaching highway. This may be impractical because of restrictive site conditions. A turning roadway at a low design speed (e.g., 15 mph) will still provide a significant benefit to the turning vehicle regardless of the speed on the approaching highway; therefore, it is not critical to ensure that the design speed on the turning roadway is within 10 mph of the approaching highway speeds.

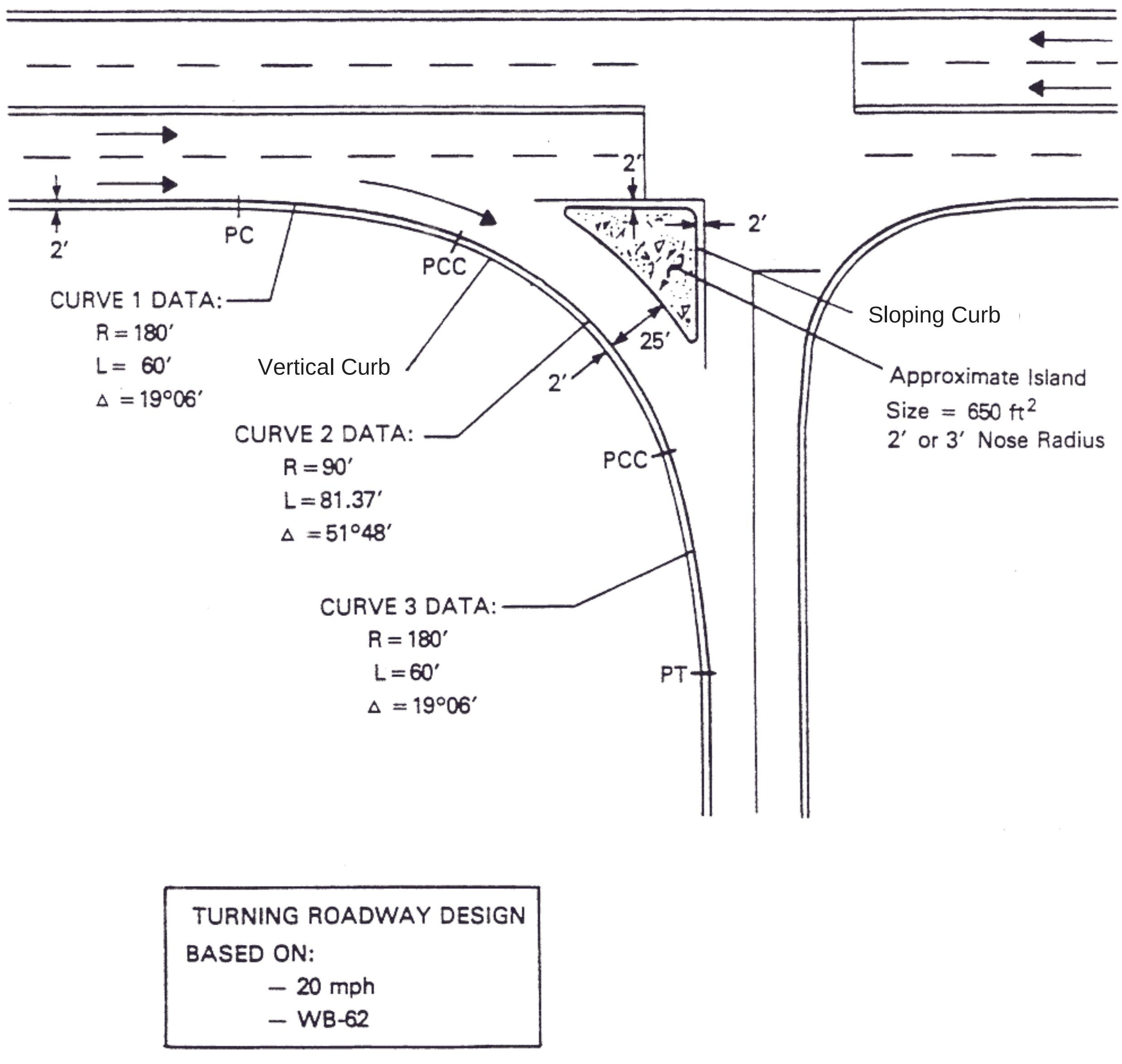


ILLUSTRATION OF A TURNING ROADWAY DESIGN

Figure 8-13

Turning Roadway Design Speed (mph)	Maximum Side Friction (f)	Super-elevation (e)	Minimum Radius (ft)	Width (ft)
15	0.35	2.0% 4.0% 6.0%	45 45 40	26
20	0.28	2.0% 4.0% 6.0%	95 85 80	25
25	0.23	2.0% 4.0% 6.0%	170 155 145	21
30	0.19	2.0% 4.0% 6.0%	275 250 230	19
35	0.17	2.0% 4.0% 6.0%	410 375 340	18
40	0.14	2.0% 4.0% 6.0%	595 535 485	17

Notes:

1. The widths in the table are based on a WB-62 but this figure can be used for the WB-67 design vehicle.

2. If a curb is present on the mainline approaching the turning roadway, the curb offset should be maintained throughout the turning roadway; i.e., the curb offset width will be in addition to the widths in the table. No additional width is necessary on the left side with or without a curb.

3. The widths in the table apply to angles of intersection of 90 degrees or less between the two main highways. The following criteria apply for intersecting angles greater than 90 degrees (for 15 mph only):

Angle of Turn	Width of Turning Roadway
105°	33 ft
120°	37 ft
135°	38 ft
150°	41 ft

DESIGNS FOR TURNING ROADWAYS

Table 8-1

8-3.02 Horizontal Curvature

At most turning roadways, a simple curve throughout will be acceptable. However, the designer should consider the use of a 3-centered compound curve, especially where the difference between the design speeds of the approaching highway and the turning roadway is more than 15 mph. This provides the driver with some transition into and out of the turning roadway.

If a 3-centered curve is used, the radius of the flatter curve should be no more than twice the radius of the sharper curve. In addition, the lengths of the entering and exiting curves should meet the criteria in Table 8-2.

Radius (ft)	**100 or less**	**150**	**200**	**250**	**300**	**400**	**500+**
Minimum Length (ft)	40	50	60	80	100	120	140
Desirable Length (ft)	60	70	90	120	140	180	200

LENGTHS OF ENTERING/EXITING CURVES
(3-Centered Curve)

Table 8-2

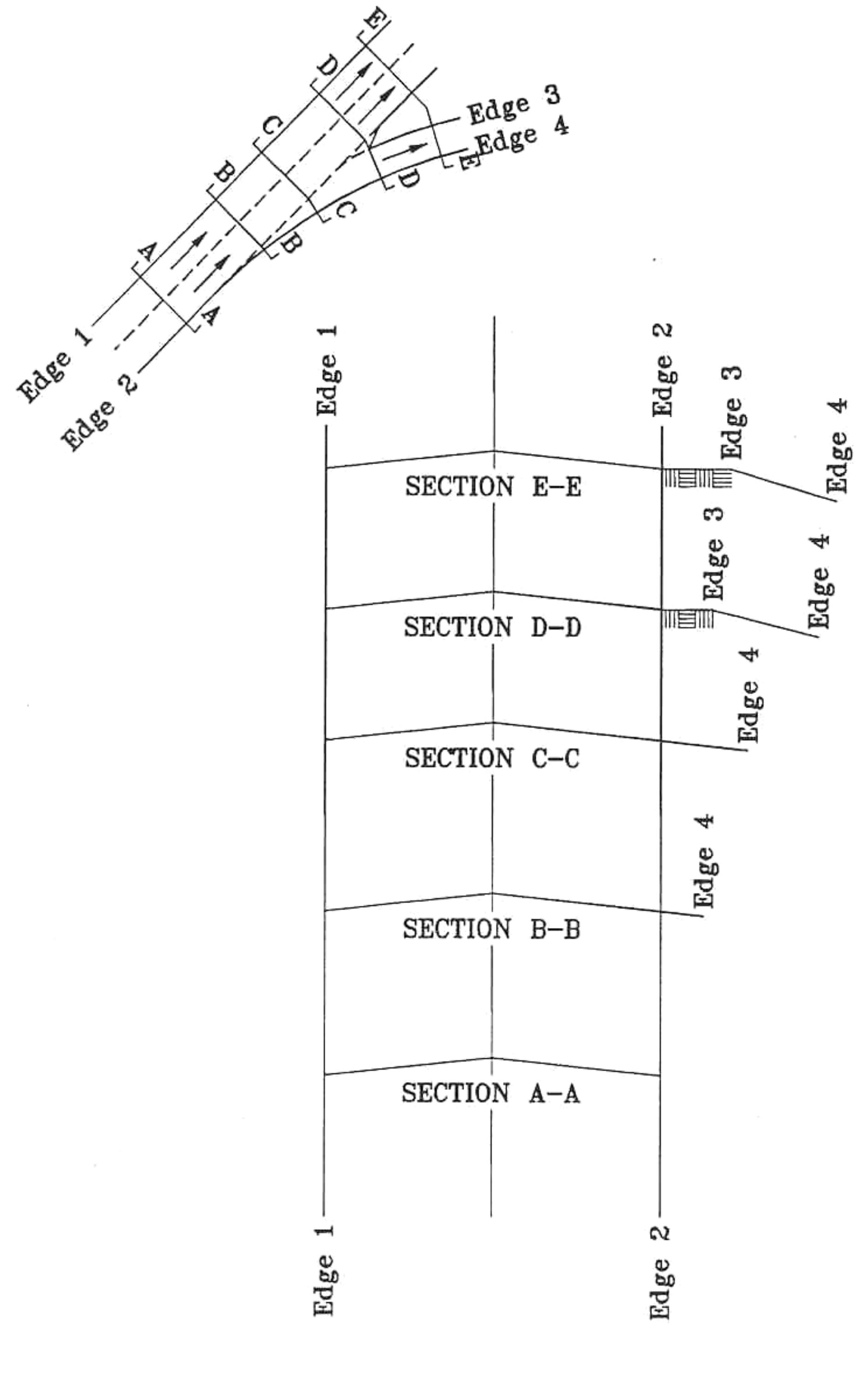
8-3.03 Superelevation

Superelevation development on turning roadways need not meet the rigid criteria used on open highways. The practicality of quickly introducing and removing a curve at an intersection requires flexibility. In many cases, the superelevation rate throughout the roadway will be 2.0%, the typical cross slope.

Figure 8-14 illustrates a schematic of superelevation development at a turning roadway. The actual development will depend upon the practical field conditions with some consideration to limiting factors. The following criteria will apply:

1. ***Rate.*** Superelevation will range between 2.0% and 6.0%.

2. ***Axis of Rotation***. The point will normally be rotated about Edge 3 in Figure 8-14.



DEVELOPMENT OF SUPERELEVATION AT TURNING ROADWAY TERMINALS

Figure 8-14

3. ***Transition Length***. This will depend upon actual field conditions. Assuming the cross slope on the approaching mainline is 2.0%, the designer should attempt to meet the following criteria (as practical):

   a. If the superelevation rate on the turning roadway will be approximately 4.0%, the transition length should be 50 feet.

   b. If the superelevation rate on the turning roadway will be approximately 6.0%, the transition length should be 100 feet.

4. ***Distribution***. Full superelevation should be reached, if actual field conditions allow, at the first 50-foot station occurring a minimum distance of 25 feet beyond section D-D in Figure 8-14. The beginning of the transition will occur at least 50 feet or 100 feet (whichever applies) in advance of the station where full superelevation is reached.

5. ***Cross Slope Rollover***. Superelevation development may also depend upon the allowable cross slope rollover between the mainline and the turning roadway. (See Table 8-3). This will likely only be a factor when a superelevated mainline is curving to the left.

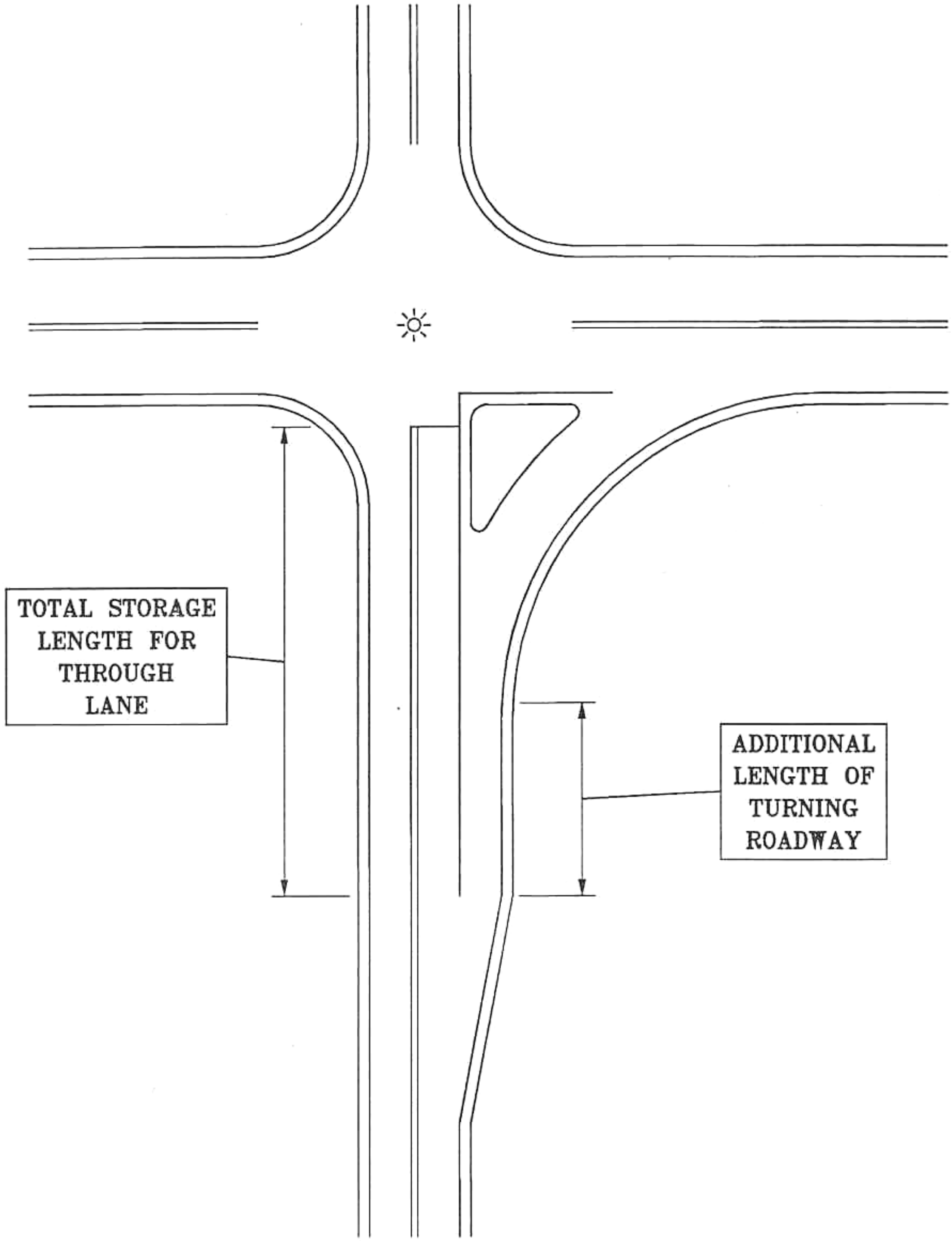
Design Speed of Curve at Section D-D (mph)	Maximum Algebraic Difference in Cross Slope at Crossover Line (percent)
≤ 20	5-8
25-30	5-6
> 30	4-5

PAVEMENT CROSS SLOPE AT TURNING ROADWAY TERMINALS

Table 8-3

8-3.04 Additional Length

At signalized intersections, the storage length on the mainline may block the entrance into the turning roadway. The designer should extend the turning roadway beyond the mainline storage length to allow access by right-turning vehicles. See the schematic in Figure 8-15.



ADDITIONAL LENGTH OF TURNING ROADWAY
(Signalized Intersections)

Figure 8-15

8-4 AUXILIARY TURNING LANES

8-4.01 Warrants for Right-Turn Lanes

Exclusive right-turn lanes should be considered:

1. at any unsignalized intersection on a two-lane urban or rural highway which satisfies the criteria in Figure 8-16;

2. at any intersection where a capacity analysis determines a right-turn lane is necessary to meet the level-of-service criteria; or

3. at any intersection where the accident experience, existing traffic operations or engineering judgment indicates a significant hazard related to right-turning vehicles.

8-4.02 Warrants for Left-Turn Lanes

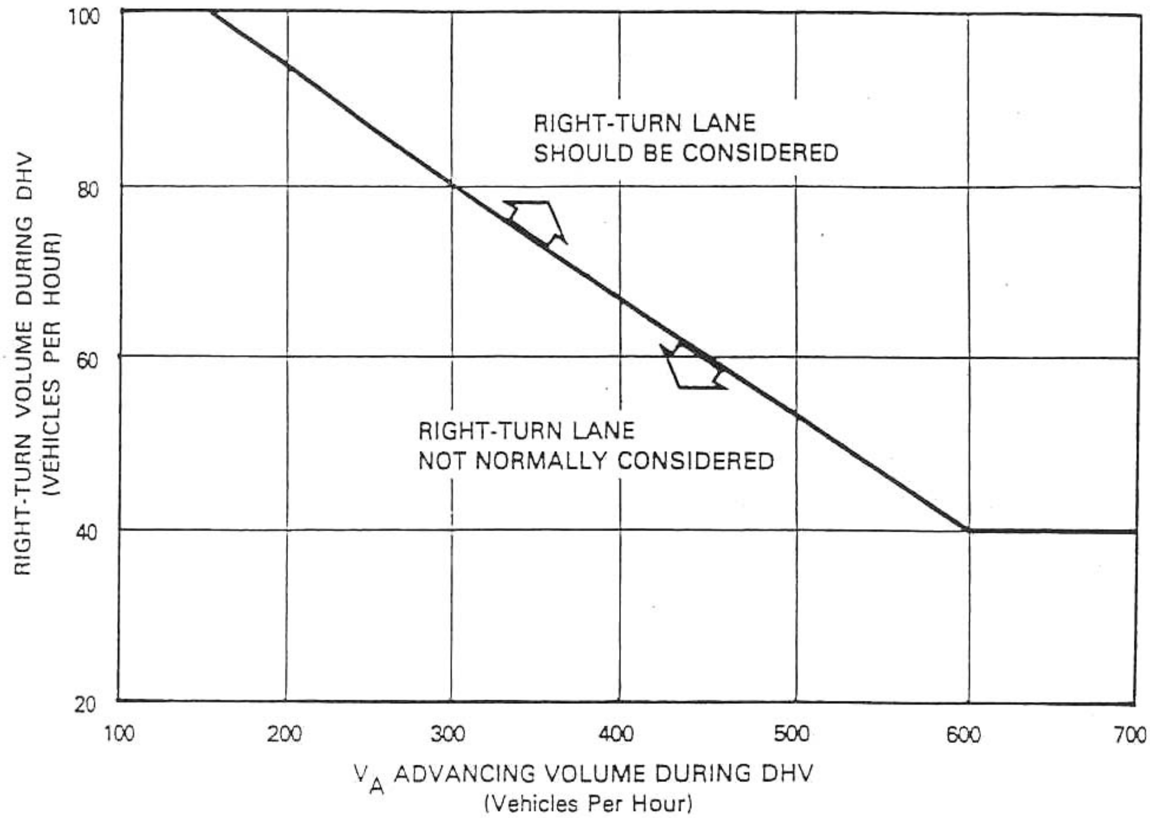
Exclusive left-turn lanes should be considered:

1. at all median openings on divided urban and rural highways without full control of access with a median wide enough to accommodate a left-turn lane;

2. at any unsignalized intersection on a two-lane highway which satisfies the criteria in Figures 8-17 to 8-19;

3. at any intersection where a capacity analysis determines a left-turn lane is necessary to meet the level-of-service criteria; or

4. at any intersection where the accident experience, existing traffic operations, adverse geometrics (e.g., restricted sight distance) or engineering judgment indicates a significant hazard related to left-turning vehicles.



Note: For highways with a design speed below 50 mph *and* DHV<300 *and* Right Turns>40, an adjustment should be used. To read the vertical axis of the chart, subtract 20 from the actual number of right turns.

Example

Given: Design Speed = 40 mph
V_A = 250 vph
Right Turns = 100 vph

Problem: Determine if a right-turn lane should be considered.

Solution: To read the vertical axis, use 100-20 = 80 vph. The figure indicates that a right-turn lane should not normally be considered, unless other factors (e.g., high accident rate) indicate a lane is needed.

GUIDELINES FOR RIGHT-TURN LANES
AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS

Figure 8-16

* * * * * * * * * *

Example 1

Given: Design Speed = 60 mph
DHV (2 way) = 600 vph
Directional Distribution = 60/40
Left Turns (at an unsignalized intersection) = 10% of heavy flow

Problem: Determine if a left-turn lane should be considered.

Solution:

STEP 1: A 60/40 directional distribution yields 360 vph in one direction and 240 vph in the other. To use Figure 8-17 (for 60 mph):

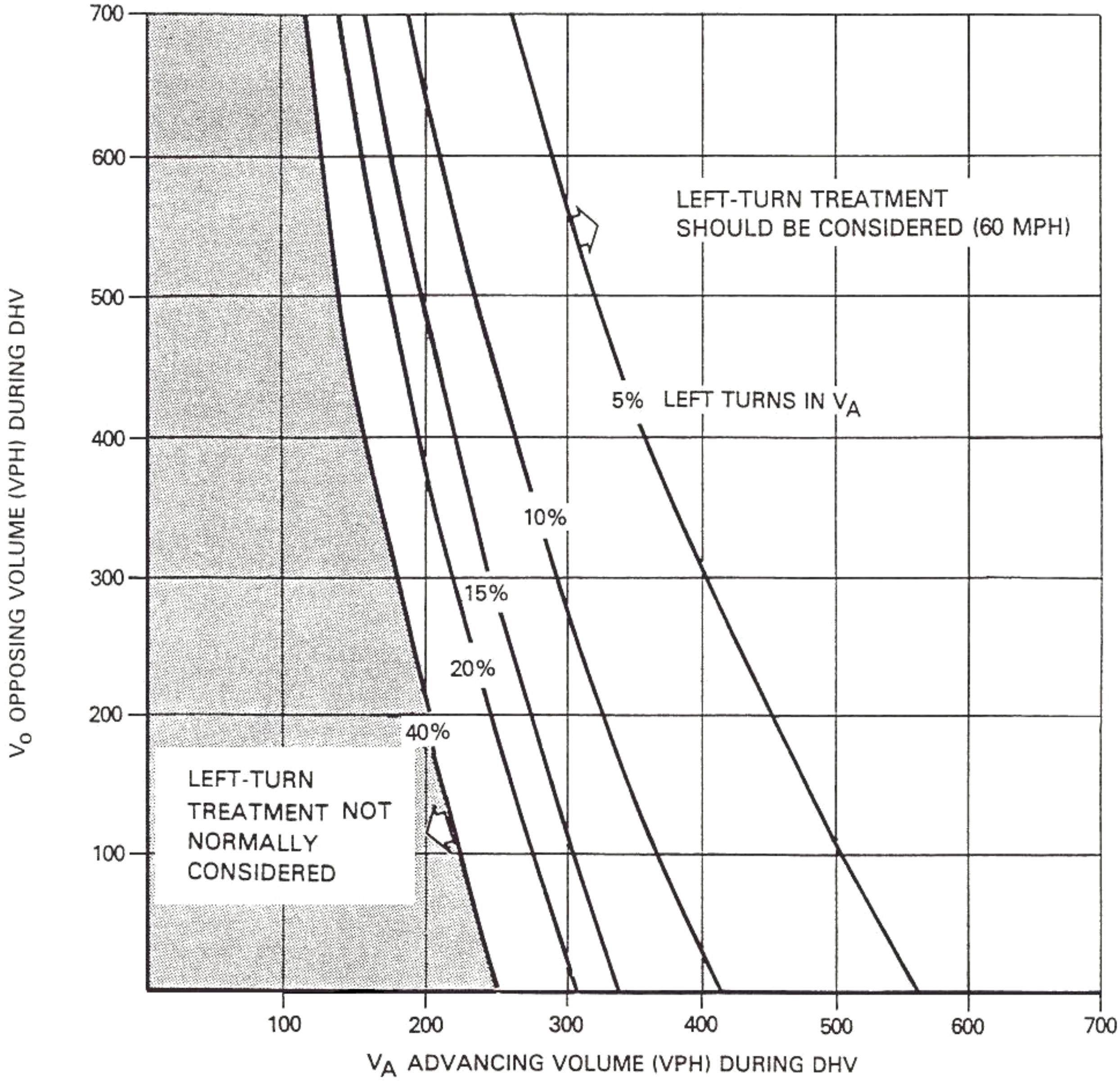
V_A = 360 vph
V_O = 240 vph

STEP 2: Use the 10 percent curve on Figure 8-17.

STEP 3: Read V_A (360 vph) and V_O (240 vph) into the chart and locate the intersection point as shown on Figure 8-17.

STEP 4: The point from Step 3 is located to the right of the 10 percent curve. Therefore, a left-turn lane should be considered.

* * * * * * * * * *



Instructions:

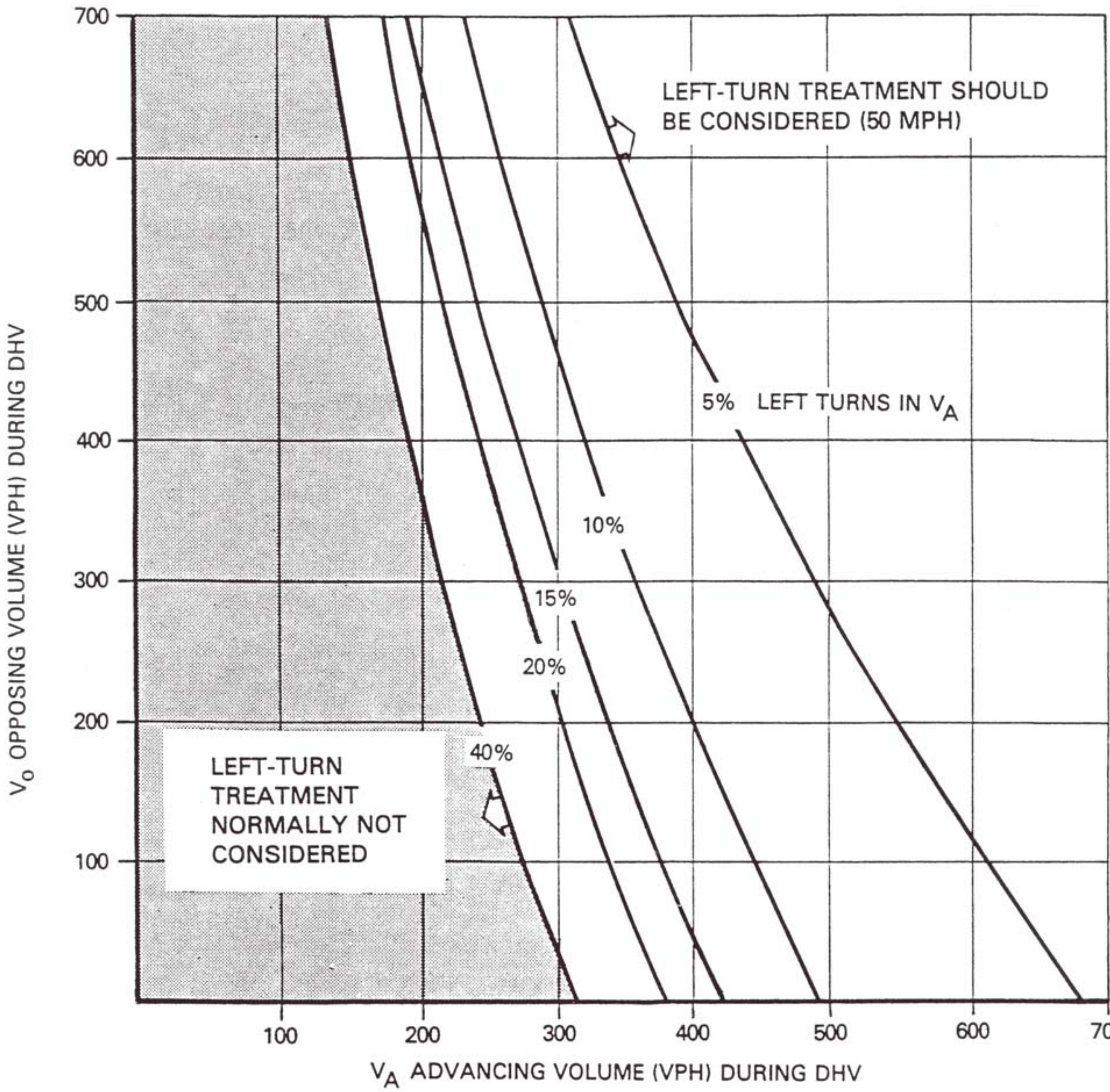
1. The family of curves represent the percent of left turns in the advancing volume (V_A). The designer should locate the curve for the actual percentage of left turns. When this is not an even increment of 5, the designer should estimate where the curve lies.

2. Read V_A and V_O into the chart and locate the intersection of the two volumes.

3. Note the location of the point in #2 relative to the line in #1. If the point is to the right of the line, then a left-turn lane is warranted. If the point is to the left of the line, then a left-turn lane is not warranted based on traffic volumes.

VOLUME WARRANTS FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS (60 mph)

Figure 8-17



Instructions:

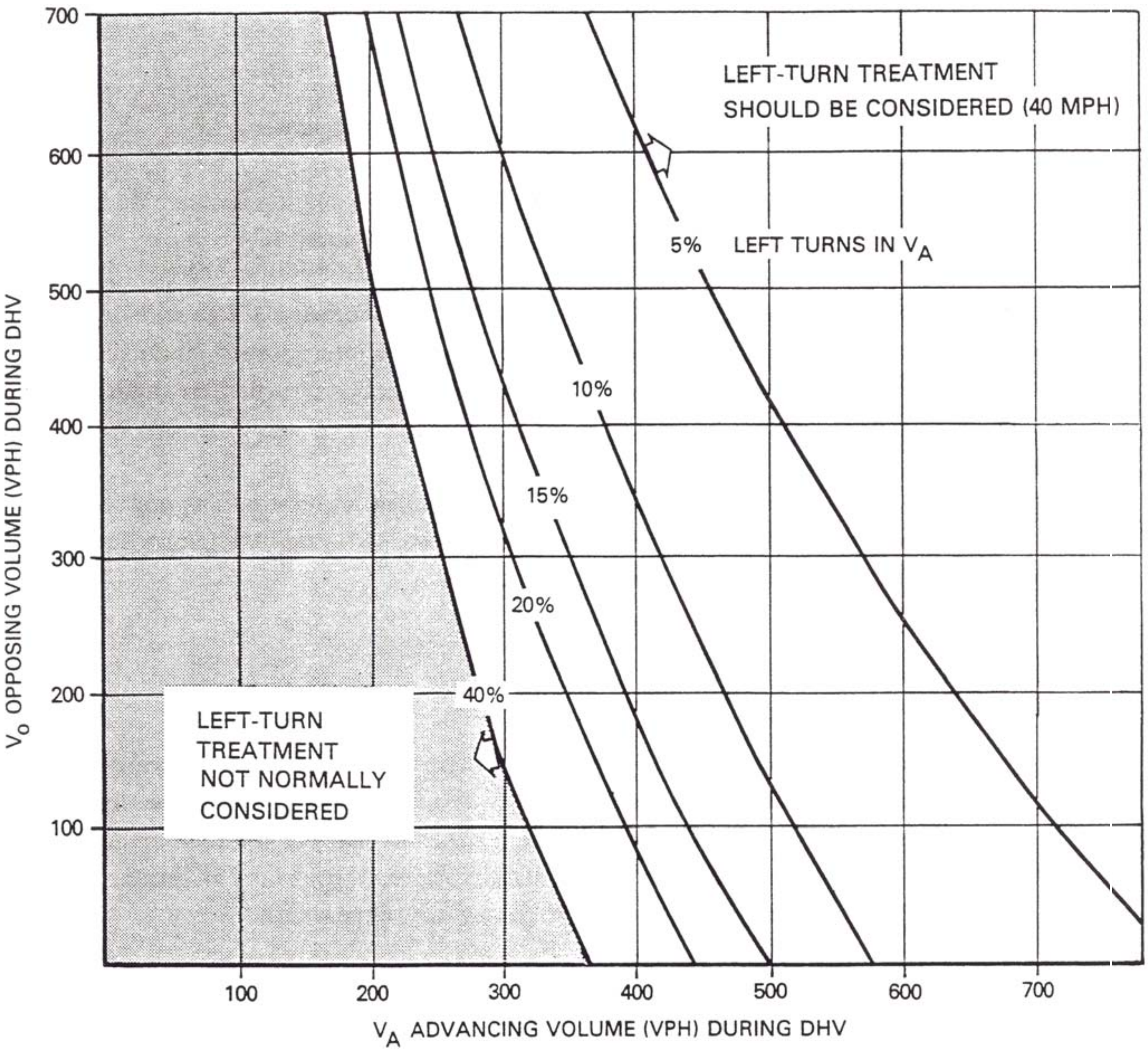
1. The family of curves represent the percent of left turns in the advancing volume (V_A). The designer should locate the curve for the actual percentage of left turns. When this is not an even increment of 5, the designer should estimate where the curve lies.

2. Read V_A and V_O into the chart and locate the intersection of the two volumes.

3. Note the location of the point in #2 relative to the line in #1. If the point is to the right of the line, then a left-turn lane is warranted. If the point is to the left of the line, then a left-turn lane is not warranted based on traffic volumes.

VOLUME WARRANTS FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS (50 mph)

Figure 8-18



Instructions:

1. The family of curves represent the percent of left turns in the advancing volume (V_A). The designer should locate the curve for the actual percentage of left turns. When this is not an even increment of 5, the designer should estimate where the curve lies.

4. Read V_A and V_O into the chart and locate the intersection of the two volumes.

5. Note the location of the point in #2 relative to the line in #1. If the point is to the right of the line, then a left-turn lane is warranted. If the point is to the left of the line, then a left-turn lane is not warranted based on traffic volumes.

**VOLUME WARRANTS FOR LEFT-TURN LANES
AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS
(40 mph)**

Figure 8-19

8-4.03 Design of Auxiliary Turning Lanes

The following criteria will apply to the design of auxiliary turning lanes:

1. ***Length***. Figure 8-20 illustrates a schematic of auxiliary lanes at an intersection. Table 8-4 presents the criteria for determining the length of the turning lane.

2. ***Width***. The width of the turn lane should be according to the functional class, urban/rural location and project scope of work. Chapters Seven and Eleven present the applicable widths for auxiliary lanes, and they present the criteria for shoulder/curb offset width from the auxiliary lane.

3. ***Parking Lanes***. A right-turn lane in an urban area will often require parking restrictions beyond the typical restricted distance from the intersection. Also, it may require relocating nearside bus stops to the far side of the intersection.

8-4.04 Bypass Lanes

Figure 8-21 illustrates the typical design for a bypass lane. This is a relatively inexpensive design to provide for through and left-turn movements at intersections. The bypass lane is appropriate for T-intersections (signalized or unsignalized) where left-turning volumes are light to moderate. It may also be appropriate at 4-way intersections; however, if right-turn volumes are high enough to warrant a right-turn lane (see Figure 8-16), do not use a bypass lane.

The decision to use either a channelized left-turn lane or the bypass lane will be based on comparative costs, accident history, right-of-way availability, through and turning traffic volumes, design speed and available sight distance.

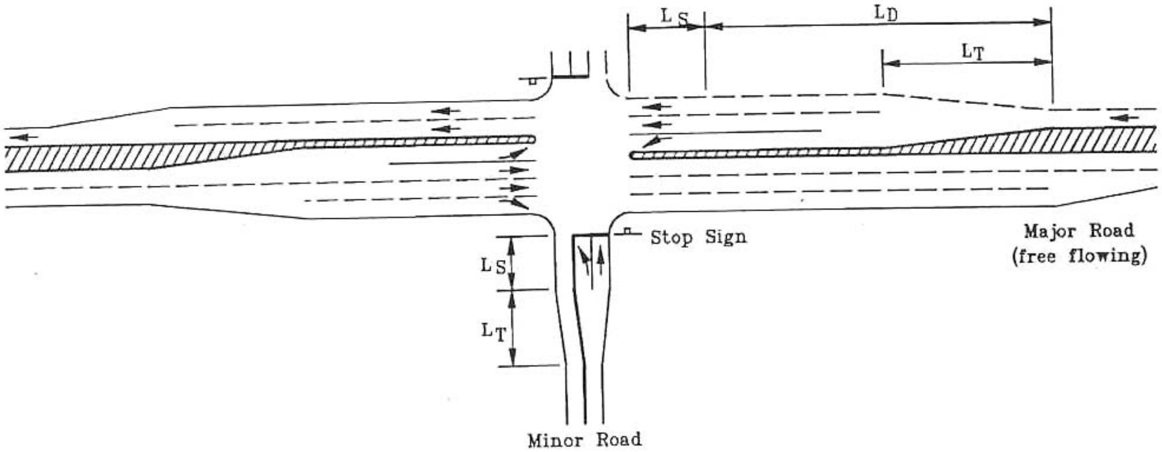
8-4.05 Dual Turn Lanes

Warrants

Dual right- and/or left-turn lanes should be considered when:

1. there is not sufficient space to provide the necessary length of a single turn lane because of restrictive site conditions (e.g., closely spaced intersections);

2. the necessary length of a single turn lane becomes prohibitive; or



Note: The schematic of the major road (free flowing) also applies to all legs of a signalized intersection.

Key:

L_T = Taper Length
L_D = Deceleration Length
L_S = Storage Length

TYPICAL AUXILIARY LANES AT AN INTERSECTION

Figure 8-20

Design Element	Design Speed (mph)	Traffic Control	Criteria (See Notes 1, 6, 7)	
Taper Rate when Straight Through Movement Changes Lanes	<45 ≥45	**All**	W x S^2/60 W x S	
Taper Rate when Straight Through Movement Stays in Lane	30 40 50 +	**All**	8:1 10:1 15:1	
Deceleration Length (L_D) **(See Notes 2, 3)**	30 40 50 60	**All (See Note 2)**	120 ft 165 ft 265 ft 370 ft	
Storage Length (L_S) **(See Note 4)**	All	**Unsignalized (See Note 4)**	**Turning DHV (vph)**	**L_S**
			<61 61-120 121-180 > 180	Minimum Length 100 150 ≥ 200
		Signalized (See Notes 4, 5, 6)	Based on 1.5 - 2.0 times the average number of cars that will store in the turning lane per cycle during the design hour.	

Notes:

1. Minimum Length. The minimum length of an auxiliary turning lane will be the taper length (L_T) plus the storage length (L_S).

2. Use of Deceleration Length. The designer should consider providing the deceleration length (L_D), if practical, at the following:
a) legs of a signalized intersection (except the truncated leg of signalized T-intersection); and
b) the free-flowing legs of a stop-controlled intersection for the left-turn lane.

   Deceleration length need not be considered at stop-control legs, nor at the truncated leg of a signalized T-intersection, nor at a right-turn lane for the free flowing leg at a stop-controlled intersection.

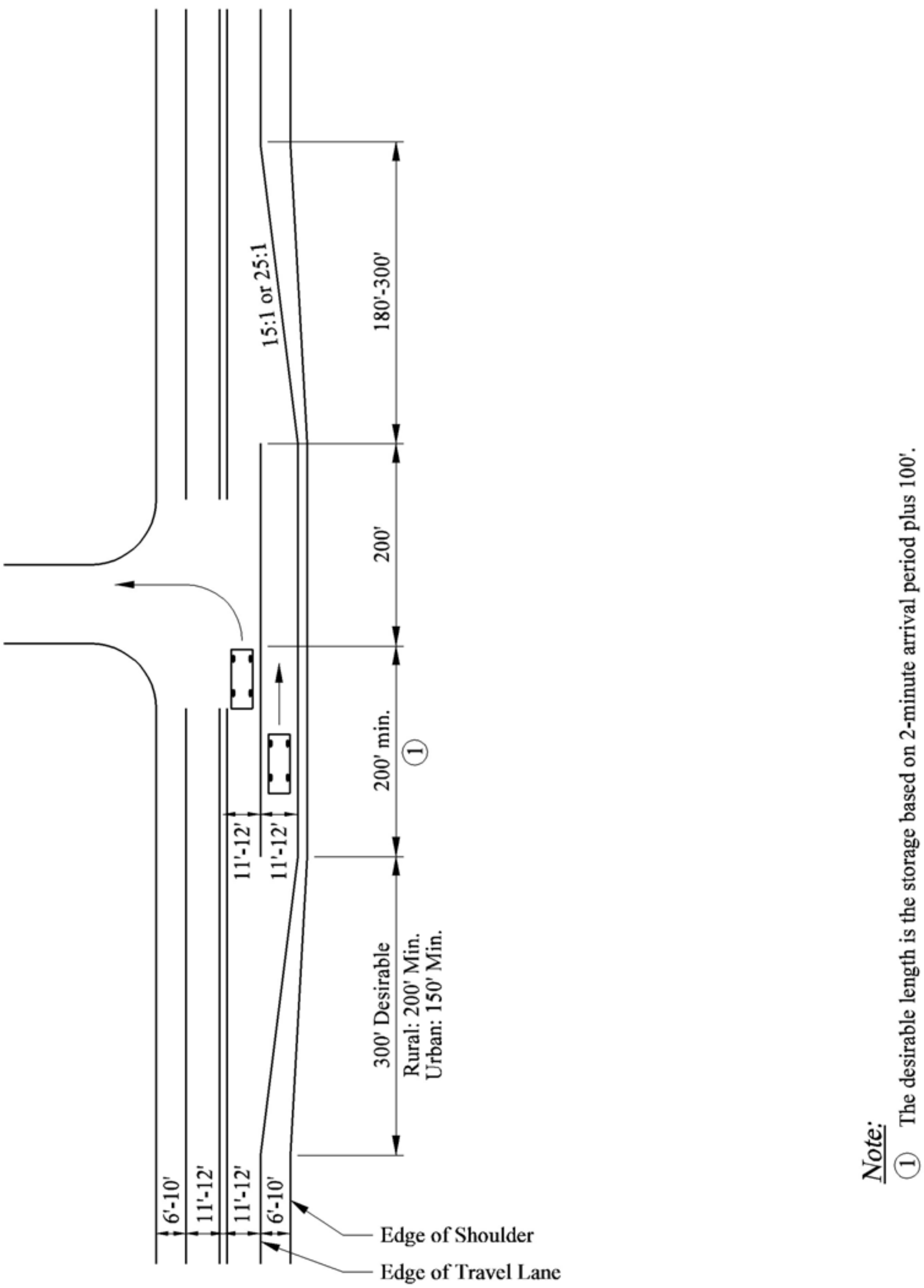
3 Measurement of Deceleration Length. As illustrated in Figure 8-20, the deceleration length (L_D) also includes the taper length (L_T). The L_D values in the table assume that the turning vehicle is traveling at a speed of approximately 5 mph below the average running speed before entering the taper.

4 .Minimum Storage Length. For all intersections where traffic volumes are too low to govern, the minimum length will be 50 ft (T≤10%) or 80 ft (T>10%), where T is the percent of trucks turning.

5. Coordination. The Traffic Engineering Division should provide the storage length (L_S) required at signalized intersections.

6. Storage Length of Through Traffic. In addition to the table criteria, the length of turning lanes at signalized intersections should exceed the calculated storage length in the through lane adjacent to the turning lane for the design hour.
7. (W = width of the travel lane in feet, S = design or posted speed of roadway in mph.)

RECOMMENDED LENGTHS OF AUXILIARY TURNING LANES
Table 8-4



TYPICAL BYPASS LANE ON A TWO-LANE HIGHWAY

Figure 8-21

3. the necessary time for a protected left-turn phase for a single lane becomes unattainable to meet the level-of-service criteria (average delay per vehicle).

Dual right-turn lanes do not work as well as dual left-turn lanes because of the more restrictive turning movements for two abreast right turns. If practical, the designer should find an alternative means to accommodate a high number of right-turning vehicles. For example, a turning roadway may accomplish this purpose.

Design

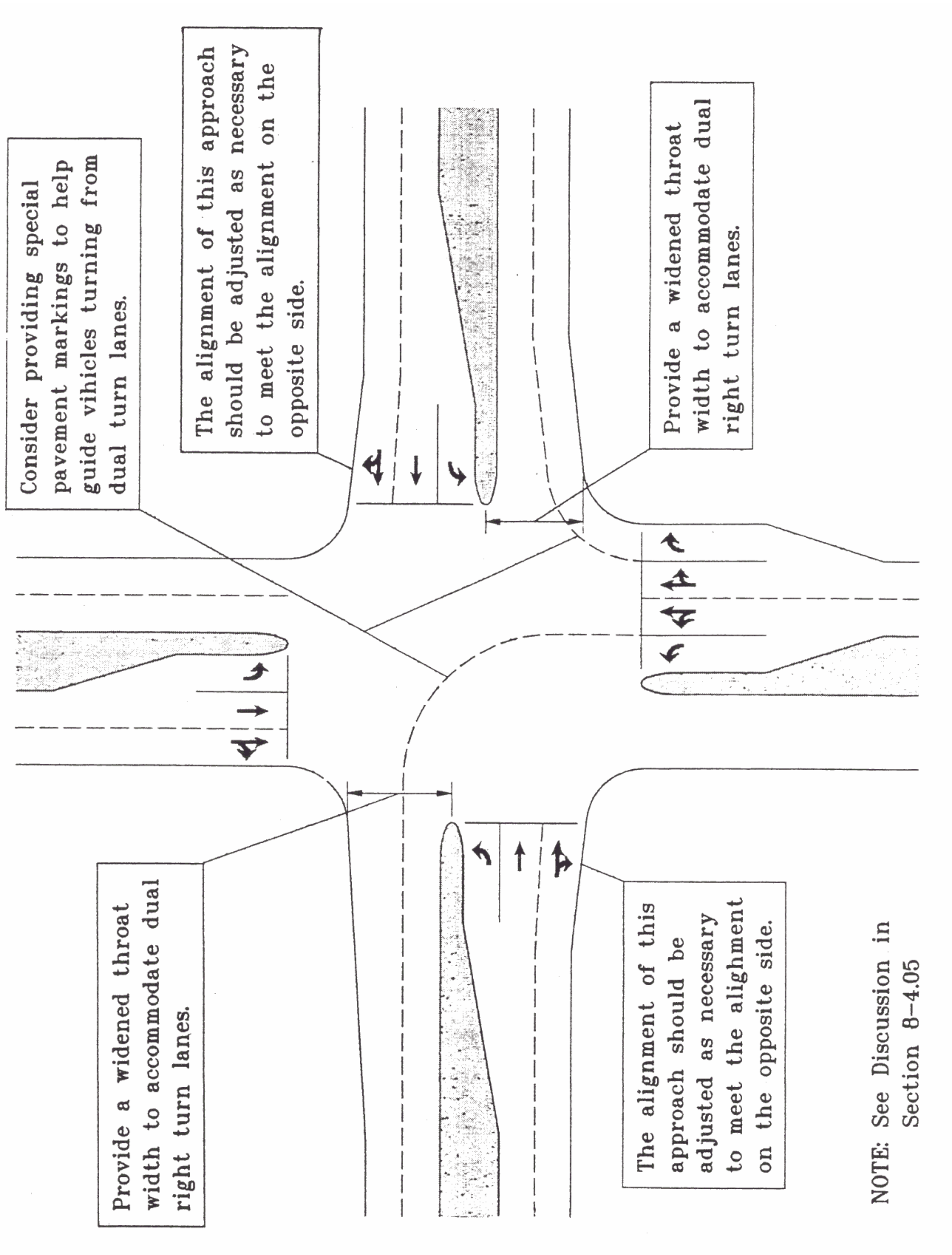
For dual turning lanes to work properly, several design elements must be carefully evaluated. Figure 8-22 presents both dual right- and left-turn lanes to illustrate the more important design elements. The designer should consider the following:

1. ***Throat Width***. Because of the off-tracking characteristics of turning vehicles, the normal width of two travel lanes may be inadequate to properly receive two vehicles turning abreast. Therefore, the receiving throat width may need to be widened. The throat width will be determined by the application of the turning templates for the design vehicles (see No. 5). The designer can expect that the width for dual turn lanes will be approximately 30-36 feet. When determining the available throat width, the designer can assume that a paved shoulder, if present at the receiving throat, will be used to accommodate two-abreast turns.

2. ***Widening Approaching Through Lanes***. If a widened throat width is provided to receive dual turn lanes, the designer should also consider how this will affect the traffic approaching from the other side. The approach to the intersection should desirably be within 6 feet of the throat width. The designer should also ensure that the through lanes line up relatively well to allow a smooth flow of traffic through the intersection. The decision on a widened approach and pavement markings should be coordinated with the Traffic Engineering Division.

3. ***Special Pavement Markings***. As illustrated in Figure 8-22, these can effectively guide two lines of vehicles turning abreast. The Traffic Engineering Division will determine the selection and placement of any special pavement markings.

4. ***Opposing Left-Turn Traffic***. If simultaneous, opposing dual left turns will be allowed, the designer should ensure that there is sufficient space for all turning movements. This is a



DESIGN OF DUAL TURN LANES

Figure 8-22

factor at all signalized intersections, but dual left-turn lanes with their two-abreast vehicles can cause special problems. If space is unavailable, it may be necessary to alter the signal phasing to allow the two directions of traffic to move through the intersection on separate phases. The intersection layout will be coordinated with the Traffic Engineering Division.

5. ***Turning Templates***. All intersection design elements for dual turn lanes must be checked by using the applicable turning templates. The designer should assume that the WB-62 design vehicle will turn from the inside lane of the dual turn lane, which is the more difficult turning maneuver. The other vehicle can be assumed to be a passenger vehicle turning side by side with the WB-62.

8-5 CONTINUOUS TWO-WAY LEFT-TURN LANES

Continuous two-way left-turn lanes (CTWLTL) are used as a cost-effective method to accommodate a continuous left-turn demand and to reduce delay and accidents. These lanes will often improve operations on roadways which were originally intended to serve the through movement but now must accommodate the demand for accessibility created by changes in adjacent land use.

All proposed locations and proposed design details for a CTWLTL should be coordinated with the Traffic Engineering Division.

8-5.01 <u>Warrants</u>

<u>Functional Class</u>

An undivided 2-lane or 4-lane urban arterial is the most common candidate for the implementation of a CTWLTL.

<u>Traffic Volumes</u>

Traffic volumes are a significant factor in the consideration of a CTWLTL. As general guidance, the following should be used:

1. On existing 2-lane roadways, a CTWLTL will often be advantageous for traffic volumes between 5,000 and 12,500 AADT.

2. On existing 4-lane highways, a CTWLTL will often be advantageous for traffic volumes between 10,000 and 25,000 AADT. For traffic volumes greater than 25,000 AADT, a raised median may be the more advantageous design selection.

Pedestrian crossing volumes are also a consideration because of the large paved area which must be traversed when a CTWLTL is present.

<u>Speed</u>

The design speed on a highway facility is a major factor in CTWLTL applications. Experience indicates that design speeds from 25 mph to 45 mph will properly accommodate a CTWLTL.

Design speeds higher than 45 mph may cause concern because of a possible increased accident potential.

Accident History

On high-volume urban arterials, traffic conflicts often result because of a significant number of mid-block left turns combined with significant opposing traffic volumes. This may lead to disproportionate numbers of mid-block, rear-end and sideswipe accidents. A CTWLTL is likely to reduce these types of accidents. The designer should review and evaluate the available accident data to determine if unusually high numbers of these accidents are occurring.

Adjacent Land Use

The mid-block, rear-end and sideswipe accidents usually result from high-density, strip commercial development along the highway. This type of land use will normally generate left turns throughout the day.

8-5.02 Design Criteria

Lane Width

Recommended lane widths for a CTWLTL and various design speeds are presented in Chapters Seven and Eleven. Existing highways that warrant the installation of a CTWLTL are often located in areas of restricted right-of-way. Conversion of the existing cross section may be difficult. To obtain the CTWLTL width, the design may have to consider several alternatives including:

1. removing an existing raised median,
2. reducing the width of existing through lanes,
3. reducing the number of existing through lanes,
4. eliminating existing parking lanes,
5. eliminating or reducing the width of existing shoulders, and/or
6. acquiring additional right-of-way to expand the pavement width by the amount needed for the CTWLTL.

Intersection Treatment

At all intersections with public roads, the CTWLTL must either 1) be terminated in advance to allow the development of an exclusive left-turn lane or 2) be extended up to the intersection area. In most cases where the CTWLTL is extended up to the intersection, the pavement marking will switch from two opposing left-turn arrows to one left-turn arrow only. When determining the intersection treatment, the following should be considered:

1. ***Functional Classification***. All intersecting arterials and many collectors will warrant an exclusive left-turn lane. The majority of intersecting local streets and some collector streets may not warrant an exclusive left-turn lane.

2. ***Turning Volumes***. The left-turn demand into the intersecting road is a factor in determining the proper intersection treatment. The following may be used as general guidance: If the minimum storage length will govern (Section 8-4.03), then it will probably be warranted to extend the CTWLTL up to the intersection (i.e., provide no exclusive left-turn lane).

3. ***Minimum Length of CTWLTL***. The CTWLTL should have sufficient length to operate properly, and the type of intersection treatment will determine the length of the CTWLTL. The minimum length will be influenced by through traffic volumes, turning volumes and operating speeds on the highway. The following guidance may be used:

   a. On facilities where $V \leq 30$ mph and/or lower traffic volumes exist, the recommended uninterrupted length of a CTWLTL should be 300-500 feet.

   b. On facilities where $V > 30$ mph and/or higher traffic volumes exist, the recommended uninterrupted length of a CTWLTL should be 500-800 feet.

   The final decision on the length of the CTWLTL will be based on site conditions.

4. ***Operational/Safety Factors***. Extending the CTWLTL up to an intersection could result in operational or safety problems. Some drivers may, for example, pass through the intersection in the CTWLTL and turn left beyond the intersection into a driveway which is very close to the intersection (e.g., within 100 feet). If operational or safety problems are known or anticipated at an intersection, this is a factor in determining the proper intersection treatment.

Transition

Transitions may be required at the beginning and ending of a CTWLTL. The length of transition should be computed by using the following equations:

1. $L = WS$ $(S>45\text{ mph})$
2. $L = WS^2/60$ $(S\leq 45\text{ mph})$

where:

L = length of transition, ft
W = width of transition, ft
S = design speed, mph

In most cases, W will be equal to one-half the width of the CTWLTL.

Traffic Control Devices

A CTWLTL requires proper signing and pavement markings to reduce indecision and misuse. Criteria for signing and markings are presented in the MUTCD. The Traffic Engineering Division will determine the proper application of traffic control devices

8-6 MEDIAN OPENINGS

8-6.01 Warrants

Non-Freeways

Desirably, median openings will be provided on divided non-freeways at all public roads and major traffic generators (e.g., shopping centers). In urban areas, this may result in close intersection spacing which impairs the operation of the facility. The following should be evaluated when determining the warrant for a median opening on urban arterials:

1. ***Signalized Intersections***. Signalized intersections should be no more closely spaced than 1600 feet. Closer spacings may impair the operation of the signals.

2. ***Unsignalized Intersections***. Median openings at unsignalized intersections will depend upon two factors. The width of the median should allow the development of an exclusive left-turn lane; if not, it may be practical to widen the median at the intersection to provide space for a channelized left-turn lane. The spacing of median openings should be large enough to allow the development of an exclusive left-turn lane with the proper length. See Figure 8-23.

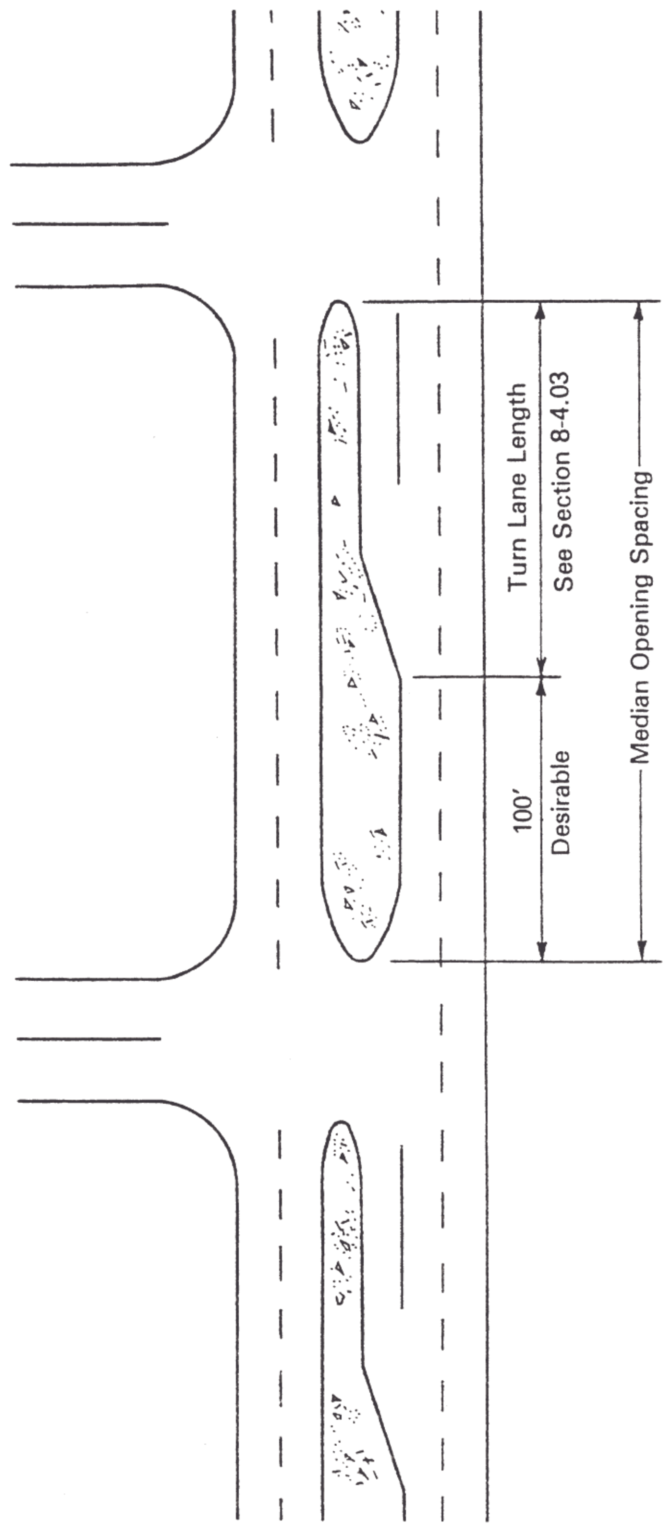
Freeways

On fully access-controlled freeways, crossovers are needed to accommodate maintenance and emergency vehicles. The following should be considered:

1. ***Warrants and Location***. Crossovers should be placed to facilitate operations such as snow plowing and considering interchange spacing. The decision on warrants and locations will be made by the Bureau of Maintenance and Operations.

2. ***Sight Distance.*** Because of the unexpected U-turn maneuver, sight distances should be high when vehicles make U-turns on freeways. At a minimum, the sight distance should be 1500 feet to the crossover from both directions.

3. ***Median Barriers.*** Emergency crossovers should be avoided where a median barrier is present. If a crossover must be provided, the barrier should be terminated as described in Section 10-6. The width of the opening should be approximately 25-30 feet



RECOMMENDED MEDIAN OPENING SPACING
(Non-Freeways)

Figure 8-23

RECOMMENDED MEDIAN OPENING SPACING
(Non-Freeways)

Figure 8-23

8-6.02 Design

Figure 8-24 illustrates the turning path for the WB-62 design vehicle, and it illustrates other design criteria at a median opening. The following will apply:

1. ***Design Vehicle***. The WB-62 design vehicle will apply to median openings.

2. ***Encroachment***. Where a single left-turn lane is used, the desirable design will be to allow the WB-62 to make the left-turn entirely within the inside lane; i.e., there will be no encroachment into the through lane adjacent to the inside lane. It will be acceptable for the WB-62 to occupy both travel lanes in its turn (see Figure 8-23).

3. ***Median Nose Design***. The shape of the nose at median openings depends on the width of the divider (m) either between the two roadway edges or between the left-turn lane and the opposing roadway edge (see Figure 8-23). This width is in contrast to the median width (M), which is measured between the edges of the two inside lanes and, therefore, includes the width of left-turn lanes, if present, and shoulder/curb offset widths.

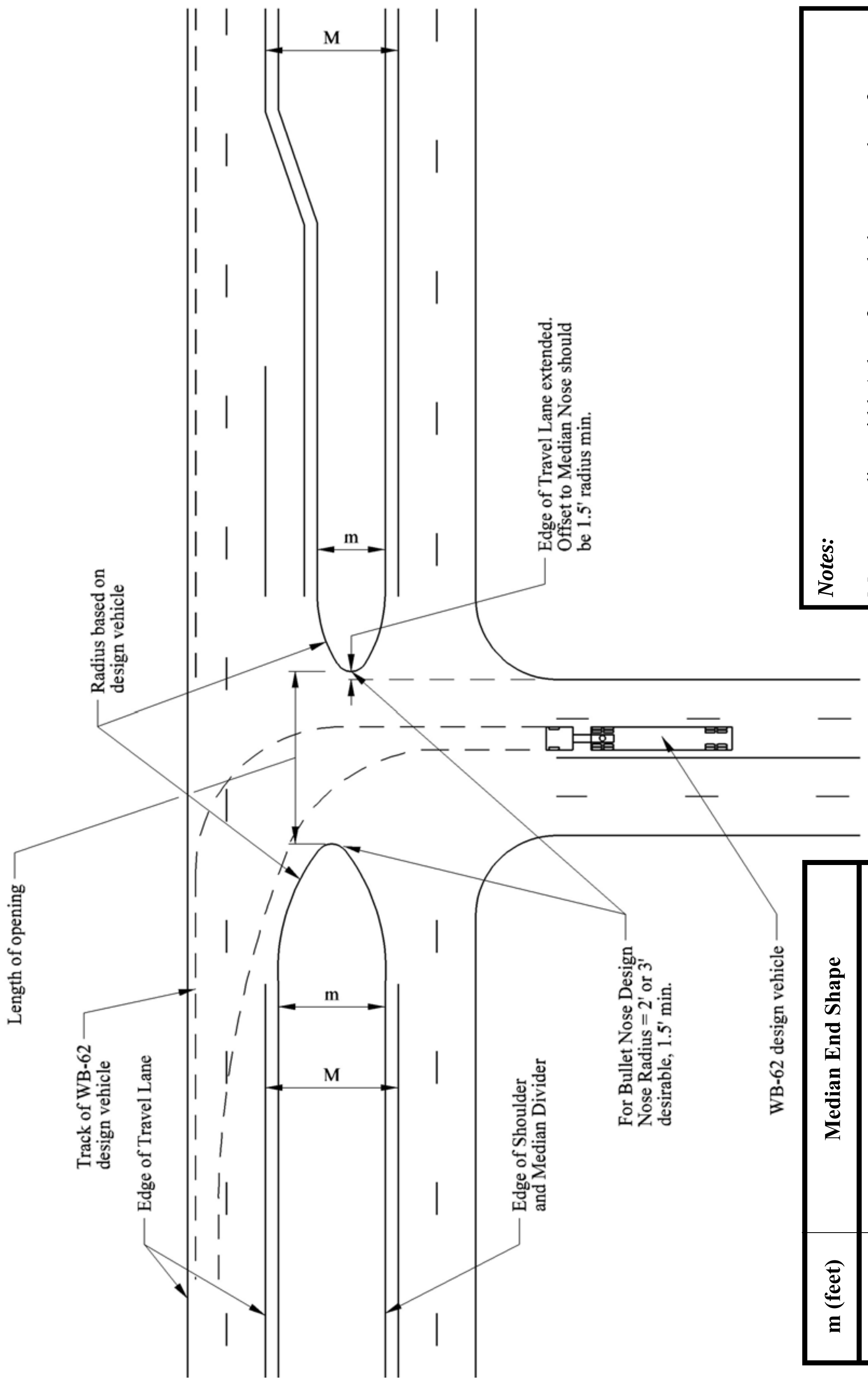
   The most common types of median noses are the semicircular end and the bullet-nose end. Recommended criteria for the selection of the median end shape based on "m" are provided in Figure 8-24. Although the semicircular design may be used for wider medians, this requires considerably larger lengths of openings.

   For the bullet-nose design, a compound curvature arrangement should be used. The radius at the tip of the nose will normally be 2-3 feet with a minimum of 1.5 feet. To determine the flatter radius, the designer should use the turning template of the design vehicle. The designer should then select a nose radius which allows the design vehicle to make the turn while at no time coming closer than 2 feet to the radius line.

4. ***Length of Opening***. The length of a median opening should properly accommodate the turning path of the design vehicle. The minimum length is 40 feet. The length of opening should be at least 4 feet greater than the width of the intersecting road. Each median opening will be evaluated individually to determine the proper length of opening. The designer should consider the following factors in the evaluation:

   a. Turning Templates. The WB-62 will be used to check the length of opening.

   b. Inside Clearance. As stated in No. 3, the WB-62 design vehicle should make the turn without coming closer than 2 feet to the median nose



Notes:

M = median width (edge of traveled way to edge of traveled way)

m = width of median divider (edge of shoulder to edge of shoulder)

m (feet)	Median End Shape
m<8	Semicircular
8≤m≤70	Bullet Nose
m>70	Treated as separate intersection

MEDIAN OPENING DESIGN

Figure 8-24

MEDIAN OPENING DESIGN

Figure 8-24

c. Lane Alignment. The designer should ensure that lanes line up properly for crossing traffic.

d. Location of Crosswalks. Desirably, pedestrian crosswalks will intersect the median nose to provide some refuge for pedestrians. Crosswalk location will be coordinated with the Traffic Engineering Division

8-7 CHANNELIZED ISLANDS

Several of the treatments described in this chapter require channelized islands within the intersection areas. These include turning roadways and channelized left-turn lanes. Figure 8-25 illustrates a typical channelization treatment as a T-intersection. Figure 8-26 illustrates several types of channelized islands with the key details for island design. These are discussed in the following sections.

8-7.01 Types of Islands

1. ***Directional Islands***. Directional islands (e.g., for turning roadways) control and direct traffic movements and guide the driver into the proper channel.

2. ***Divisional Islands***. Divisional islands separate opposing traffic flows, alert the driver to the crossroad ahead and regulate traffic through the intersection. These islands are often introduced at intersections on undivided highways. The minimum length of divisional islands is 25 feet.

Channelized islands may be some combination of flush or raised, paved or grass, and triangular or elongated. Raised islands formed by curbs should be used where pedestrian traffic is significant, where traffic control devices are needed within the island, and where the design speed is 45 mph and below.

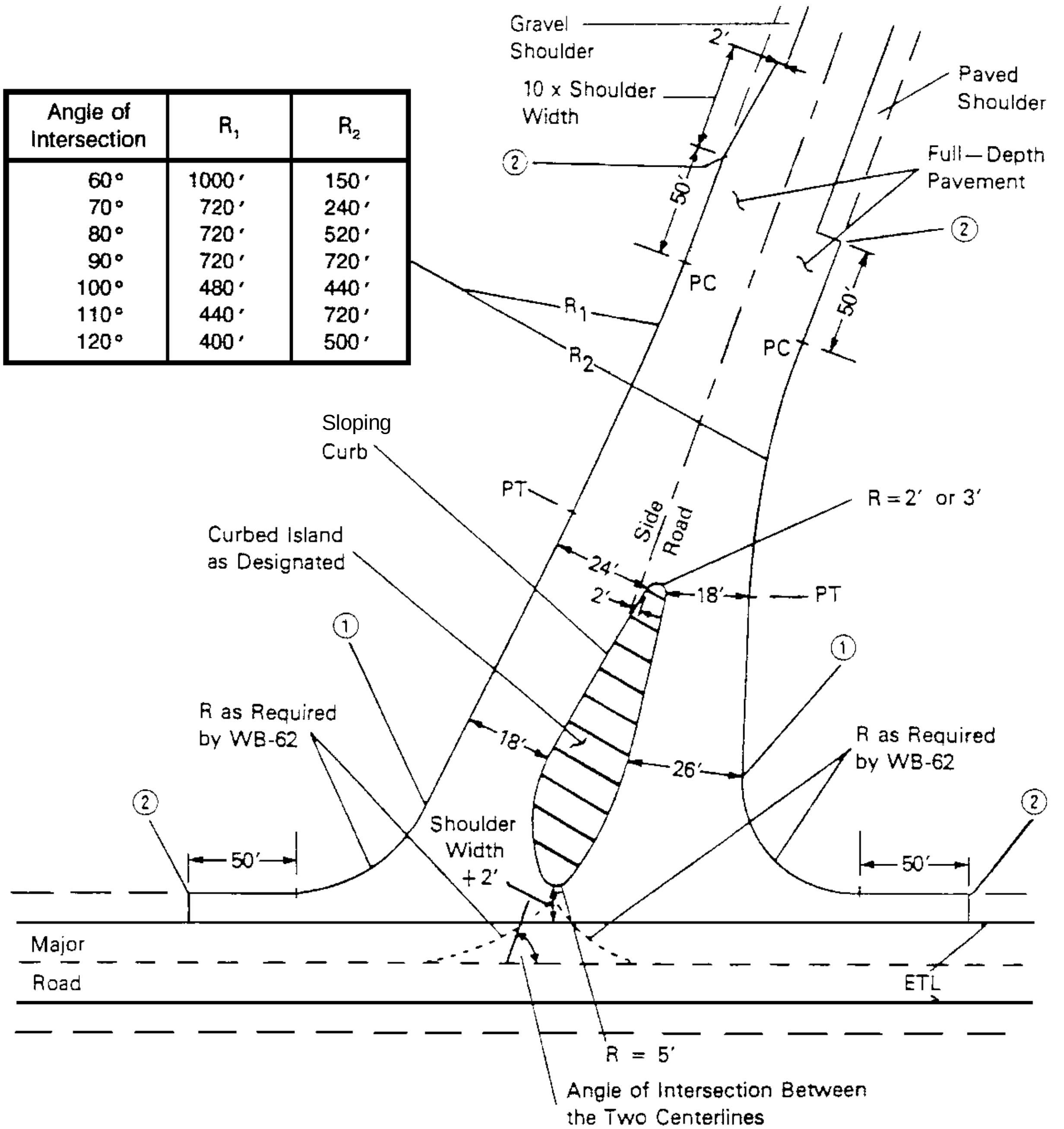
8-7.02 Minimum Size

Figure 8-26 indicates minimum sizes for channelized islands.

8-7.03 Delineation/Approach Treatment

Channelized islands should be delineated by sloping curb or pavement markings based on their size, location and function.

Angle of Intersection	R_1	R_2
60°	1000′	150′
70°	720′	240′
80°	720′	520′
90°	720′	720′
100°	480′	440′
110°	440′	720′
120°	400′	500′

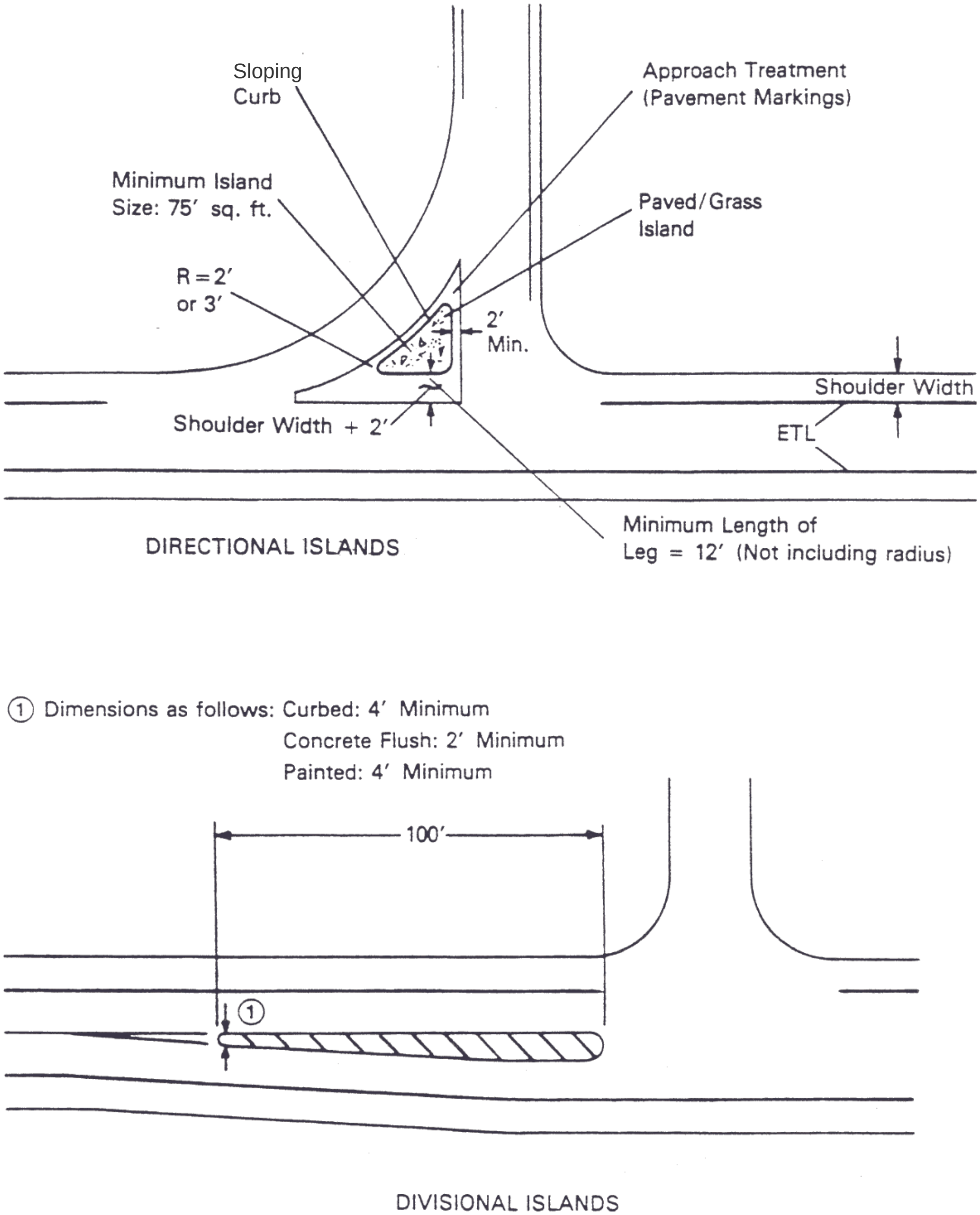


① Where one road has sloping and the other has vertical curb, ① marks the point where the switch is made

② When curb is not present on the major and/or side road leading up to the intersection, ② marks the points where curb will begin and end. In these cases, sloping curb will be used. Existing vertical curbs leading up to the intersection will be matched.

TYPICAL CHANNELIZATION TREATMENT
(T-Intersection)

Figure 8-25



CHANNELIZED ISLANDS

Figure 8-26

8-8 ENTRANCE DESIGN

8-8.01 Design Criteria

Entrance Types (Definitions)

1. Residential. One providing access to a single-family residence or 1-4 residential units.

2. Commercial/Industrial. One providing access to an office, retail or institutional building, to an apartment building or to a warehouse, truck terminal, etc. Such buildings are customarily serviced by trucks. A centralized retail development, such as a community or regional shopping center, may have one or more driveways especially designed, signed and located to provide access for trucks. These also are classified as commercial/industrial entrances.

Entrance Sight Distance

Section 8-1 discusses intersection sight distance (ISD) criteria for intersections with public roads. Desirably, these criteria will also apply to sight distances at entrances. For entrances with low volumes, it is not warranted to explore extraordinary measures to improve sight distance. The designer should check for sight obstructions in the vicinity of the entrance such as large trees or hedgerows. To perform the check, it is reasonable to assume an eye location of approximately 10 feet from the edge of travel lane.

Auxiliary Lanes

Deceleration and acceleration lanes should be considered at high-volume entrances, especially on high-speed, high-volume arterials. Section 8-4 further discusses the design and warrants for auxiliary lanes, and these also apply to high-volume entrances. In addition to traffic-volume considerations, it may be warranted to provide a right-turn lane into the entrance if the change in grade is abrupt at the entrance.

Side Slopes

Driveway side slopes should be the same as the mainline side slope. This applies for a minimum distance of the roadside clear zone for the mainline. Beyond this point, driveway side slopes may be steeper.

Material

During the preliminary or final field inspection, the Construction Team Member may designate if the project being inspected is in an area of the State where the available gravel is sandy and difficult to compact for a good driving surface. Should this be the case, the designer will select the entrance note that calls for gravel entrances to be constructed of 11 inch Aggregate Subbase Course-Gravel and 3 inch Untreated Aggregate Surface Course and estimate accordingly. This note will be added to the general notes.

Drainage

At some entrances, the potential may exist for melting water to flow along snowbanks and down the entrance toward a building. To alleviate this, the designer will include a hump at the edge of shoulder for all entrances under these conditions whether or not a curb is present. The design of this hump will be according to the Standard Details. This design may be omitted or modified if excessive right-of-way damage is caused by it or if there is no potential drainage problem. Also, it is not intended for use on undeveloped properties that are served by woods and field entrances

Design Vehicle

The following design vehicles apply:

1. ***Residential Entrances***. Use the P design vehicle.
2. ***Commercial/Industrial Entrances***. Use the WB-62 design vehicle.

The application of a turning template will determine the combination of width and turning radii into the entrance which will accommodate the design vehicle.

Grades at Skewed Entrances

When designing skewed drives, the grade shown is usually along the centerline of the drive. When the skew is sufficiently large, this causes the grade along the inside edge to be considerably steeper than that shown along the centerline and, in a number of cases, will require the resident to lengthen and regrade the entrance. The designer should show grades along the inside edge of all drives that are skewed 30 degrees or more. The inside edge is that edge that forms an acute angle with the roadway. This policy should avoid needing additional grading rights and determining more accurately whether or not a drive should be paved or not because of percent grade.

8-8.02 Entrance Figures

Typical Entrance Profiles

Figure 8-27 presents design criteria for entrances where no sidewalks exist; Figure 8-28 applies to entrances where sidewalks are present.

Typical Entrance Plan Views

Typical plan views of entrances are:

1. Figure 8-29 "Residential Entrance onto Uncurbed Highway (Gravel Shoulders)."

2. Figure 8-30 "Residential Entrance onto Uncurbed Highway (Paved Shoulders)."

3. Figure 8-31 "Commercial/Industrial Entrance onto Uncurbed Highway (Gravel Shoulders)."

4. Figure 8-32 "Commercial/Industrial Entrance onto Uncurbed Highway (Paved Shoulders)."

5. Figure 8-33 "Commercial/Industrial Double Entrances onto Uncurbed Highway (Gravel Shoulders)."

6. Figure 8-34 "Commercial/Industrial Double Entrances onto Uncurbed Highway (Paved Shoulders)."

7. Figure 8-35 "Corner Lot Entrance onto Rural Highway

8. Figure 8-36 "Shopping Center Entrance onto Highway (Paved Shoulders)."

9. Figure 8-37 "Residential Entrance onto Curbed Highway (With/Without Sidewalks)."

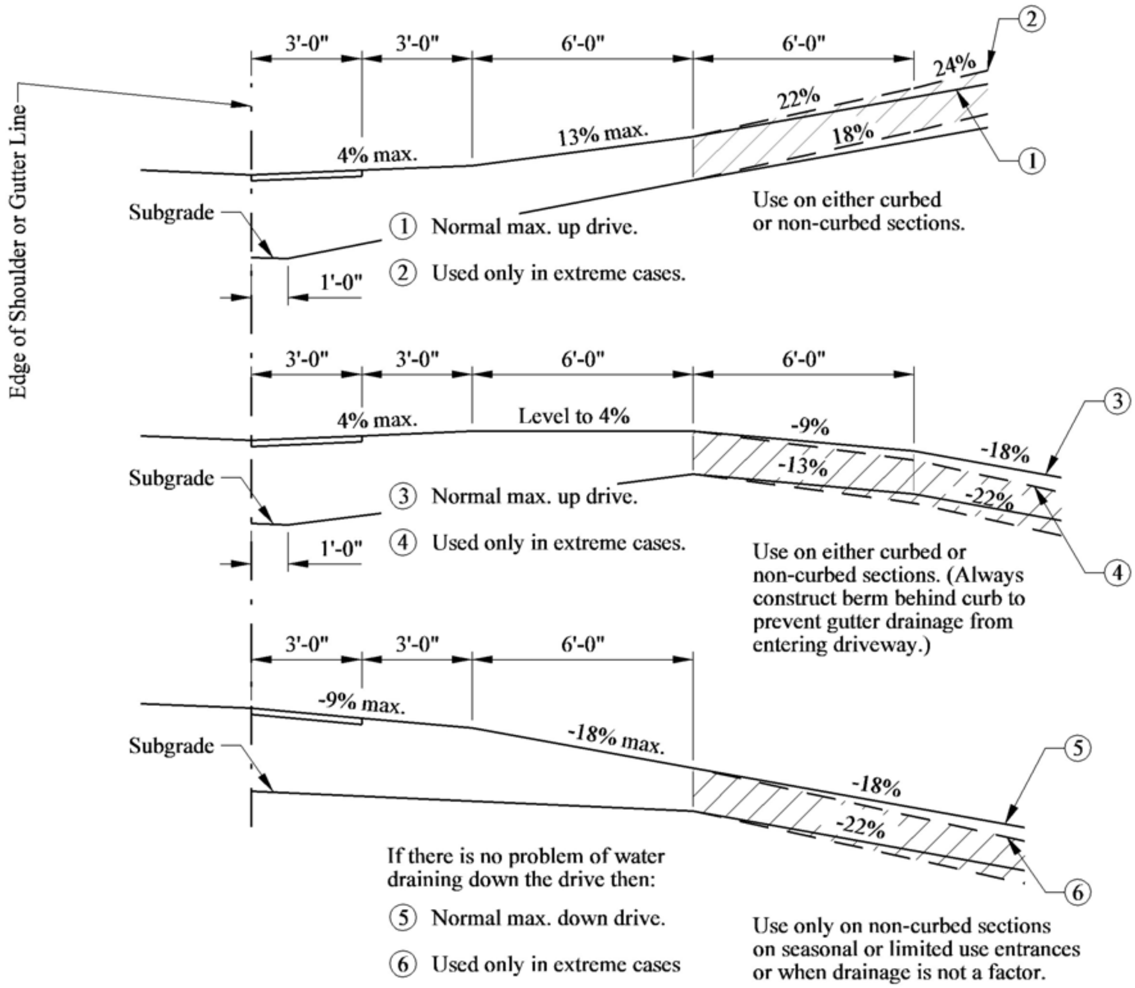
10. Figure 8-38 "Commercial/Industrial Entrance onto Curbed Highway (With/Without Sidewalk)."

11. Figure 8-39 "Commercial/Industrial Entrance onto Curbed Highway (Curbed Entrance)."

12. Figure 8-40 "Commercial/Industrial Double Entrances onto Curbed Highway (Narrow Right-of-Way)."

13. Figure 8-41 "Commercial/Industrial Double Entrances onto Curbed Highway (Wide Right-of-Way)."

14. Figure 8-42 "Corner Lot Entrance onto Urban Highway (Narrow Right-of-Way)."



General Notes:

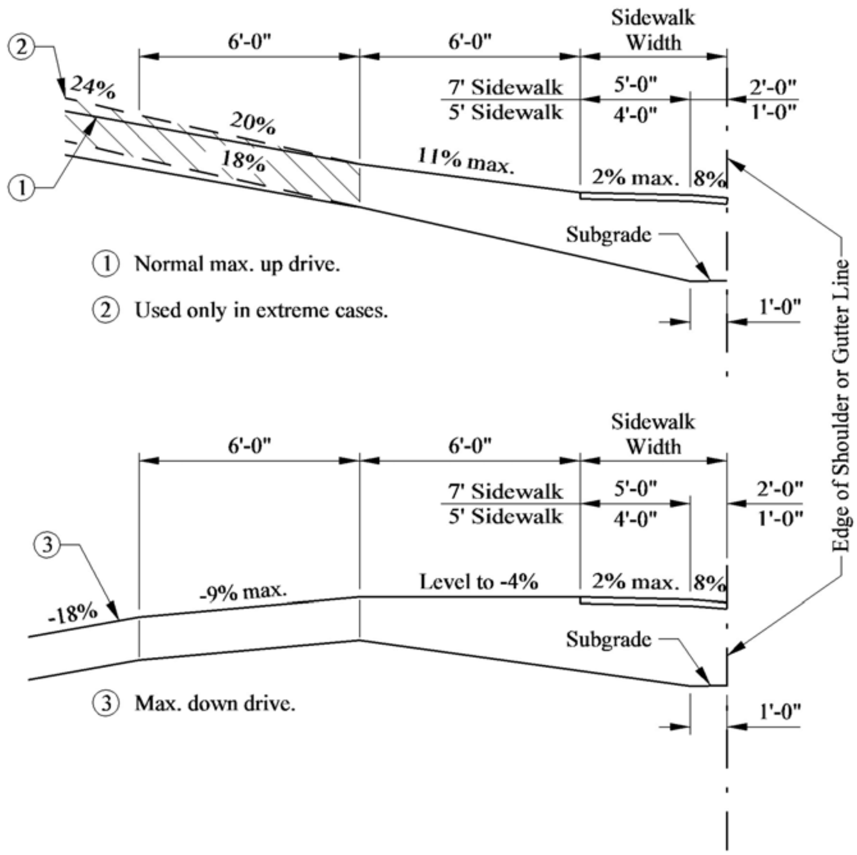
1. The first 3 feet shown as pavement will be paved only when abutting a paved shoulder to a non-paved entrance.
2. All residential or commercial drives 10% and over will be paved.

Notes on Maximum Driveway Profiles:

1. These profiles are a guide for the majority of cases, but should be field checked when the main line grade is steep (4% to 6% or greater) or the angle of approach to the drive is unusual.
2. Generally the majority of drives on a project will be built with flatter profiles than these maximum cases.
3. When grading drives which are flatter than the maximum profiles the following rule of thumb should be used: Do not exceed a grade % change of more than 9% in a 6-foot increment of driveway length. This applies to both up and down profiles.

TYPICAL ENTRANCE PROFILE
(No Sidewalk)

Figure 8-27



General Notes:

① The sidewalk width will be paved in all cases.

② All residential or commercial drives 10% and over will be paved.

Notes on Maximum Driveway Profiles:

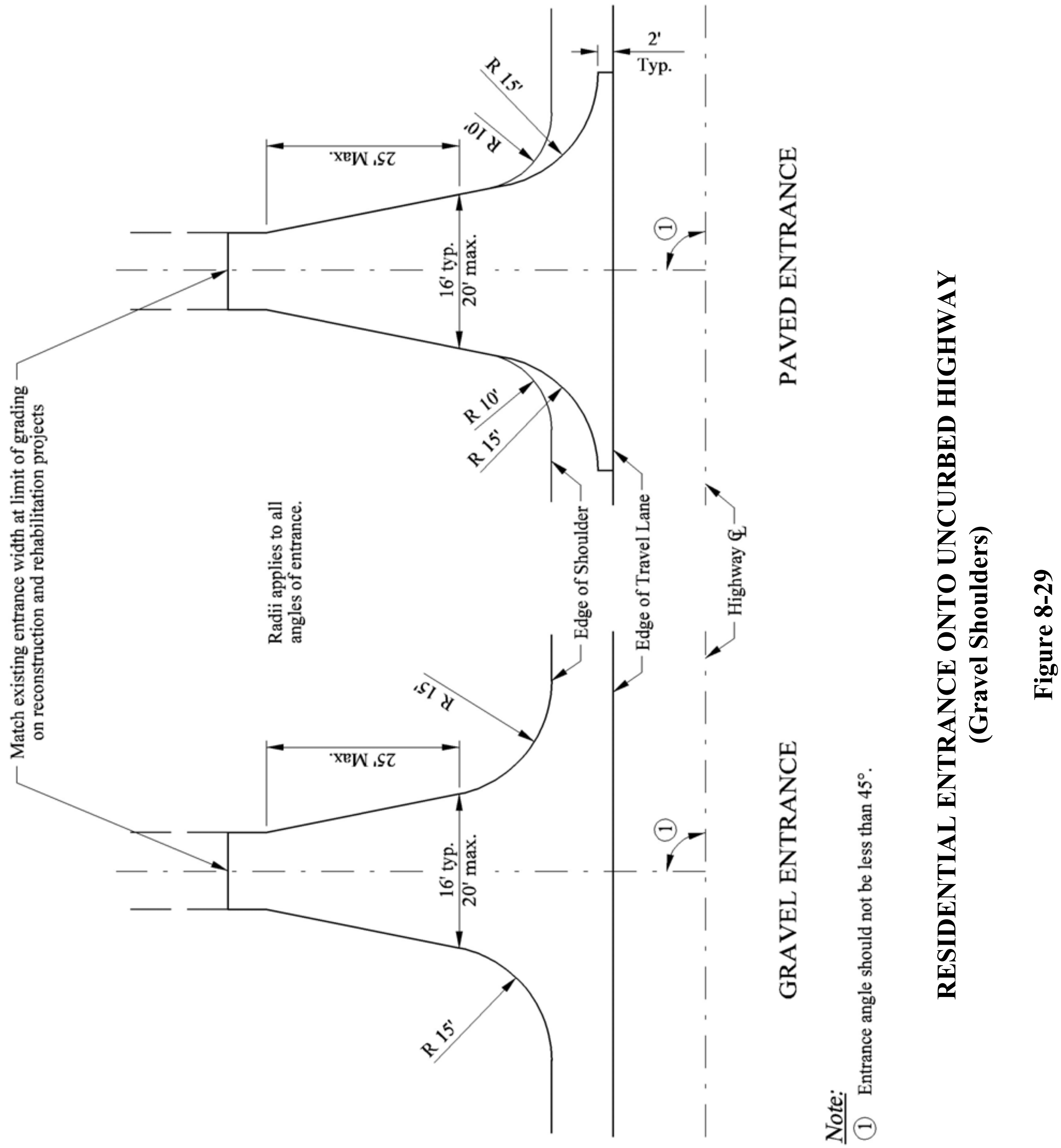
① These profiles are a guide for the majority of cases, but should be field checked when the main line grade is steep (4% to 6% or greater) or the angle of approach to the drive is unusual.

② Generally the majority of drives on a project will be built with flatter profiles than these maximum cases.

③ When grading drives which are flatter than the maximum profiles the following rule of thumb should be used: Do not exceed a grade % change of more than 9% in a 6-foot increment of driveway length. This applies to both up and down profiles.

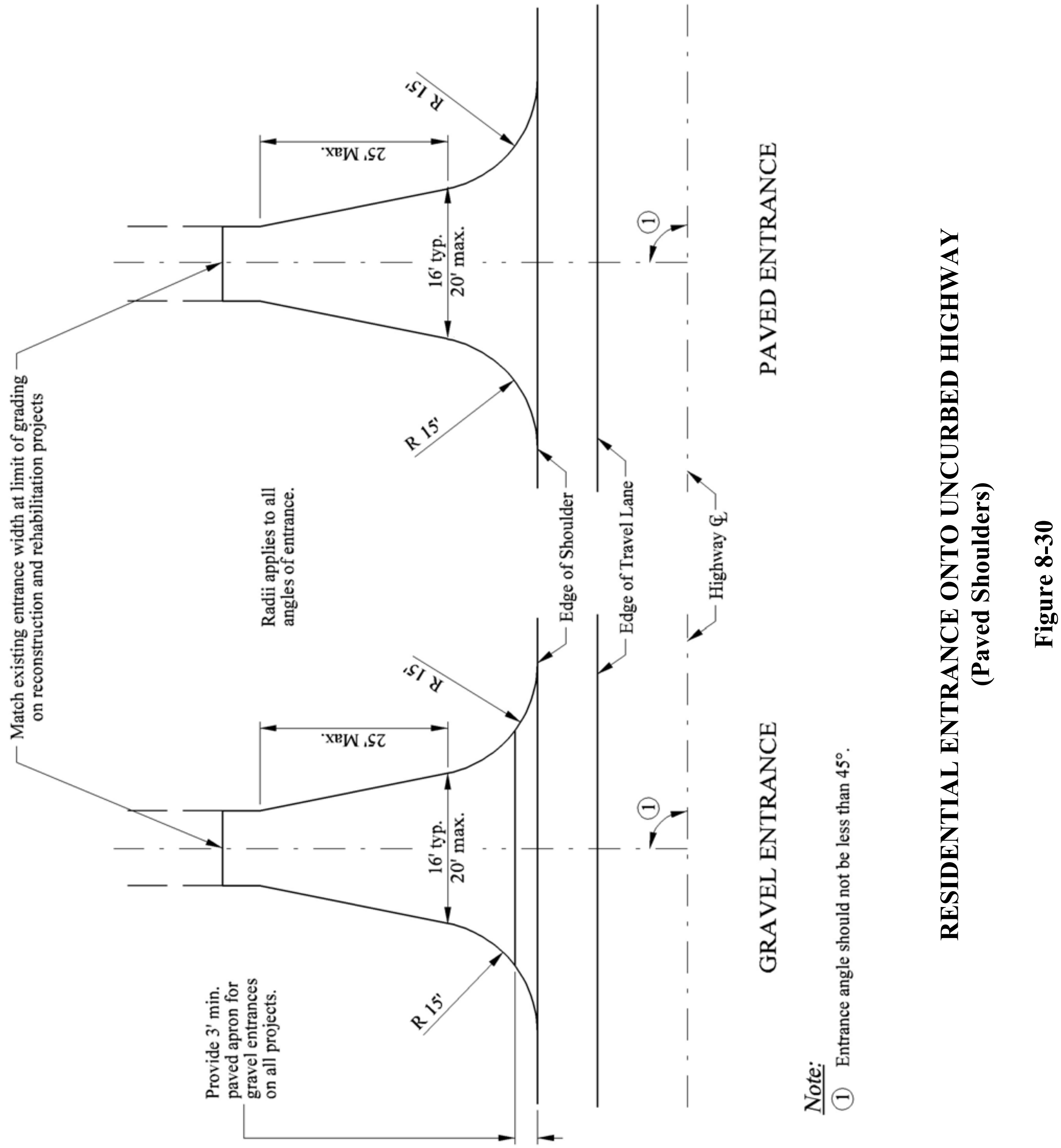
TYPICAL ENTRANCE PROFILE
(Sidewalk)

Figure 8-28



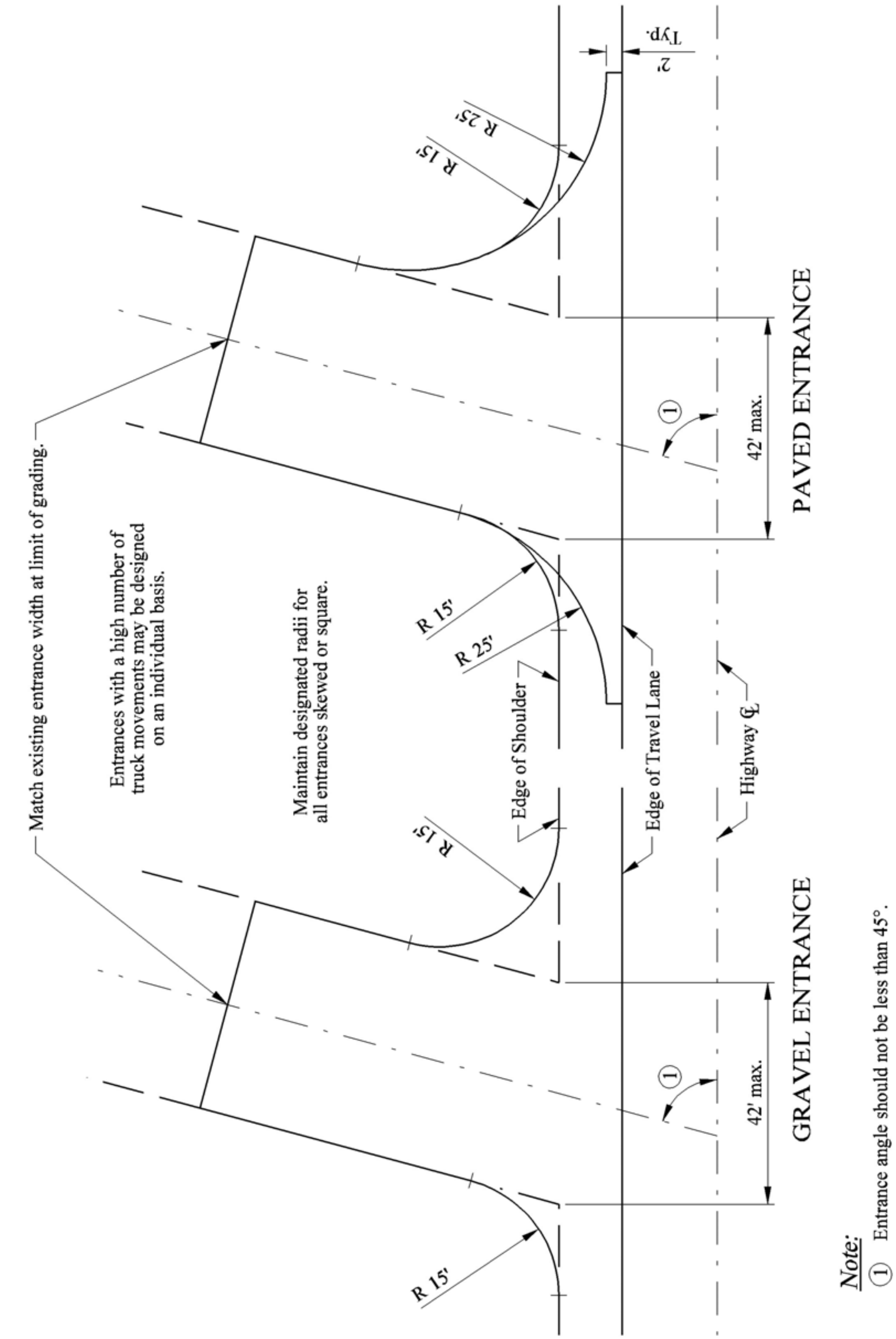
RESIDENTIAL ENTRANCE ONTO UNCURBED HIGHWAY
(Gravel Shoulders)

Figure 8-29



RESIDENTIAL ENTRANCE ONTO UNCURBED HIGHWAY
(Paved Shoulders)

Figure 8-30

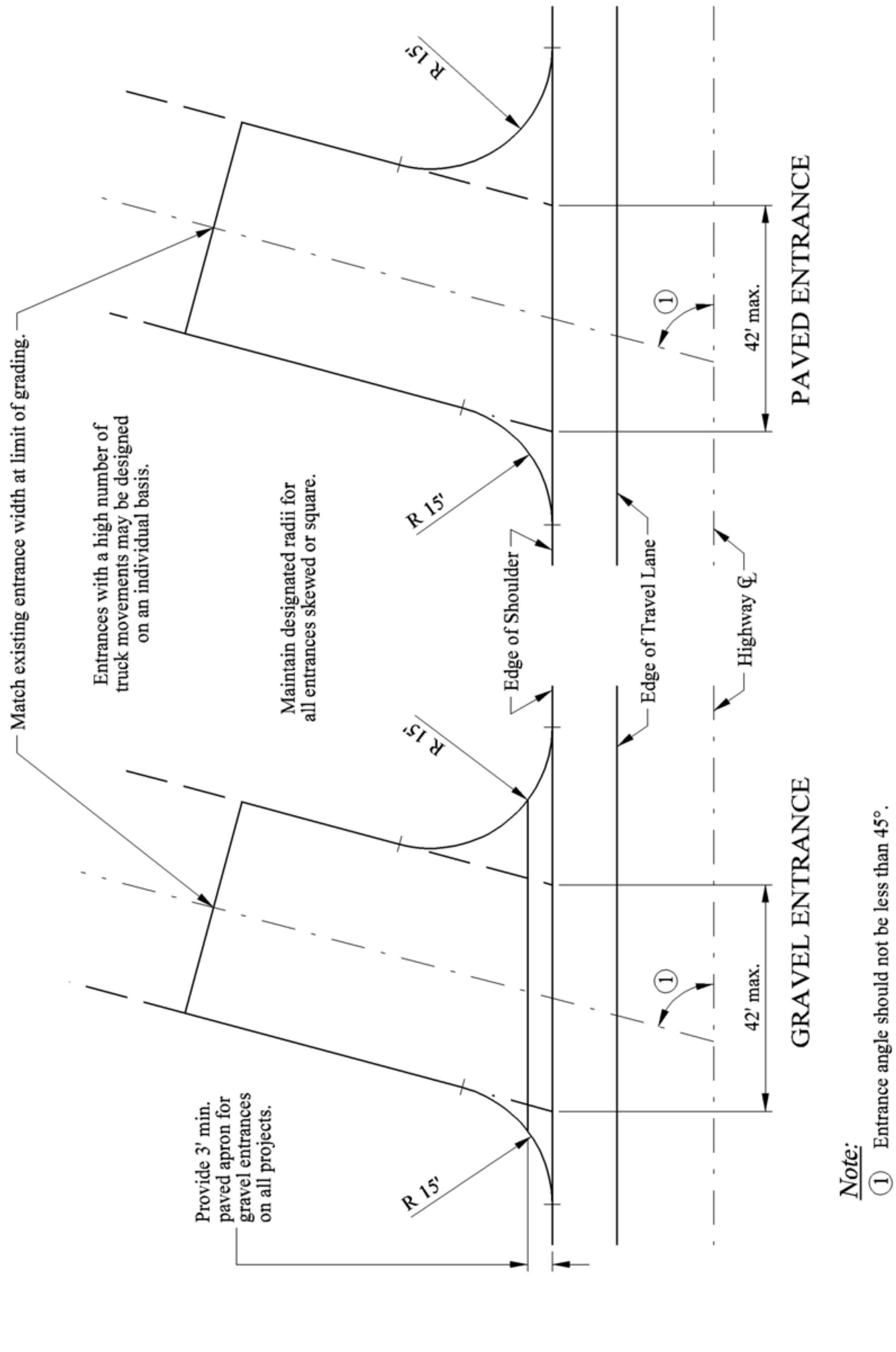


COMMERCIAL/INDUSTRIAL ENTRANCE ONTO UNCURBED HIGHWAY
(Gravel Shoulders)

Figure 8-31

COMMERCIAL/INDUSTRIAL ENTRANCE ONTO UNCURBED HIGHWAY
(Gravel Shoulders)

Figure 8-31

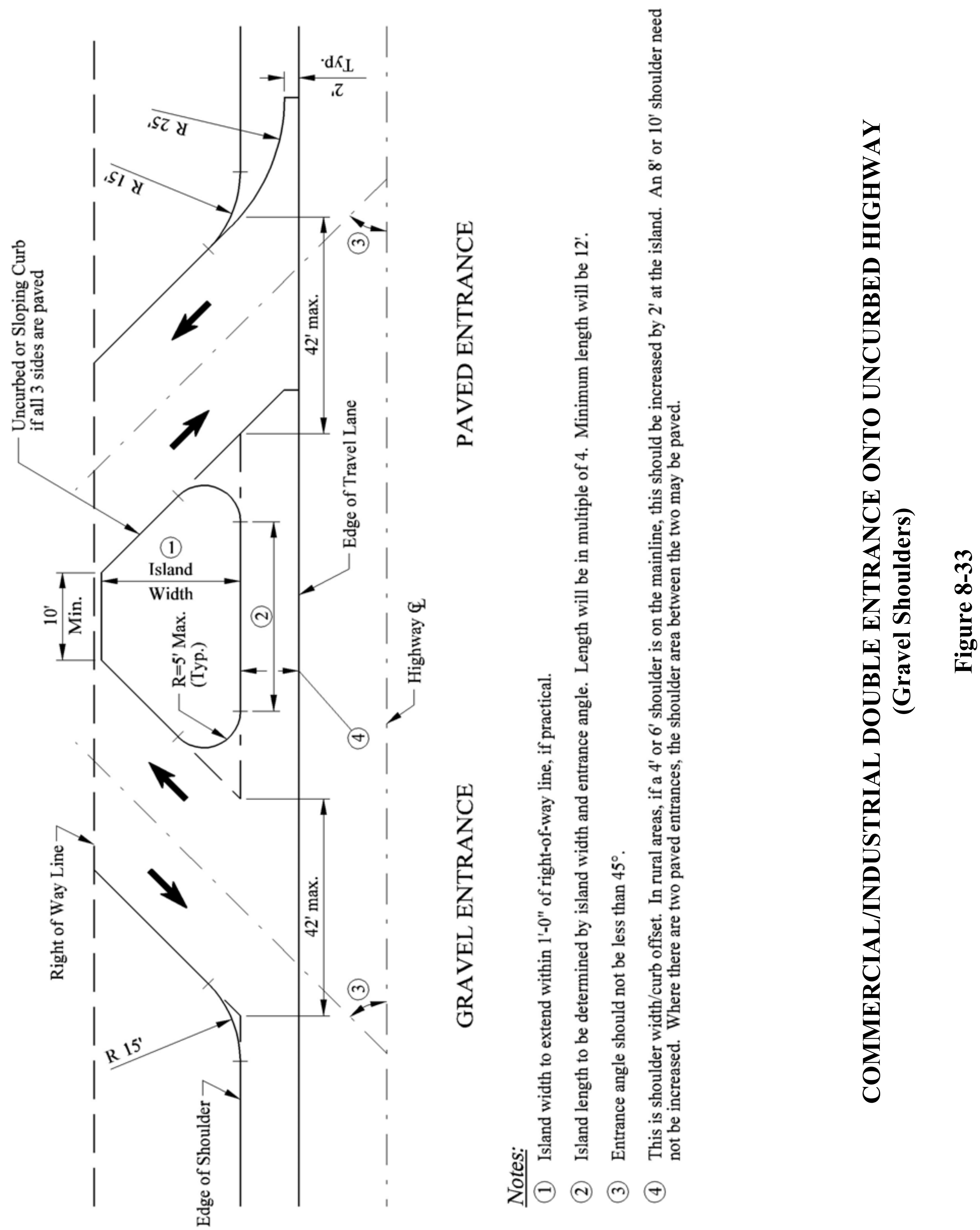


COMMERCIAL/INDUSTRIAL ENTRANCE ONTO UNCURBED HIGHWAY
(Paved Shoulders)

Figure 8-32

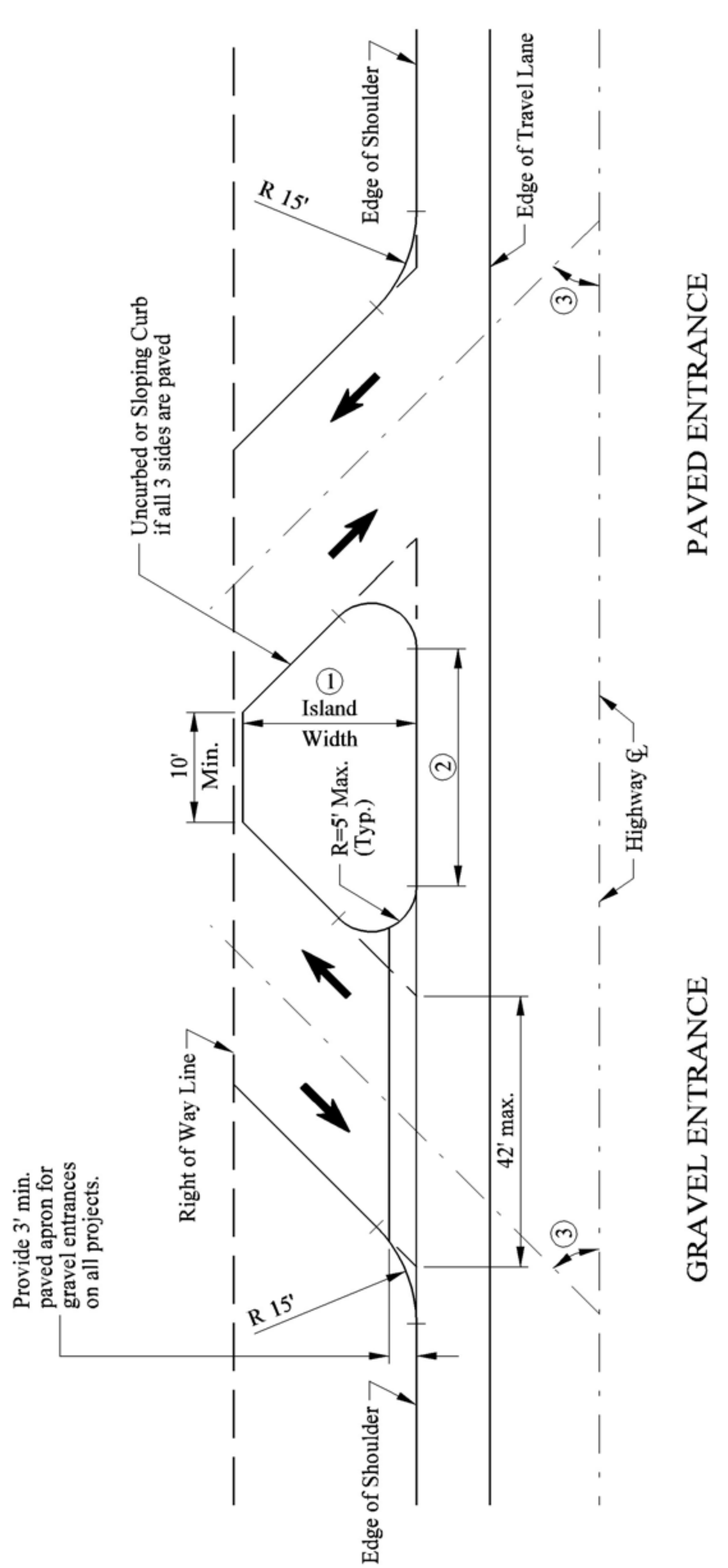
COMMERCIAL/INDUSTRIAL ENTRANCE ONTO UNCURBED HIGHWAY
(Paved Shoulders)

Figure 8-32



COMMERCIAL/INDUSTRIAL DOUBLE ENTRANCES ONTO UNCURBED HIGHWAY
(Gravel Shoulders)

Figure 8-33



Notes:

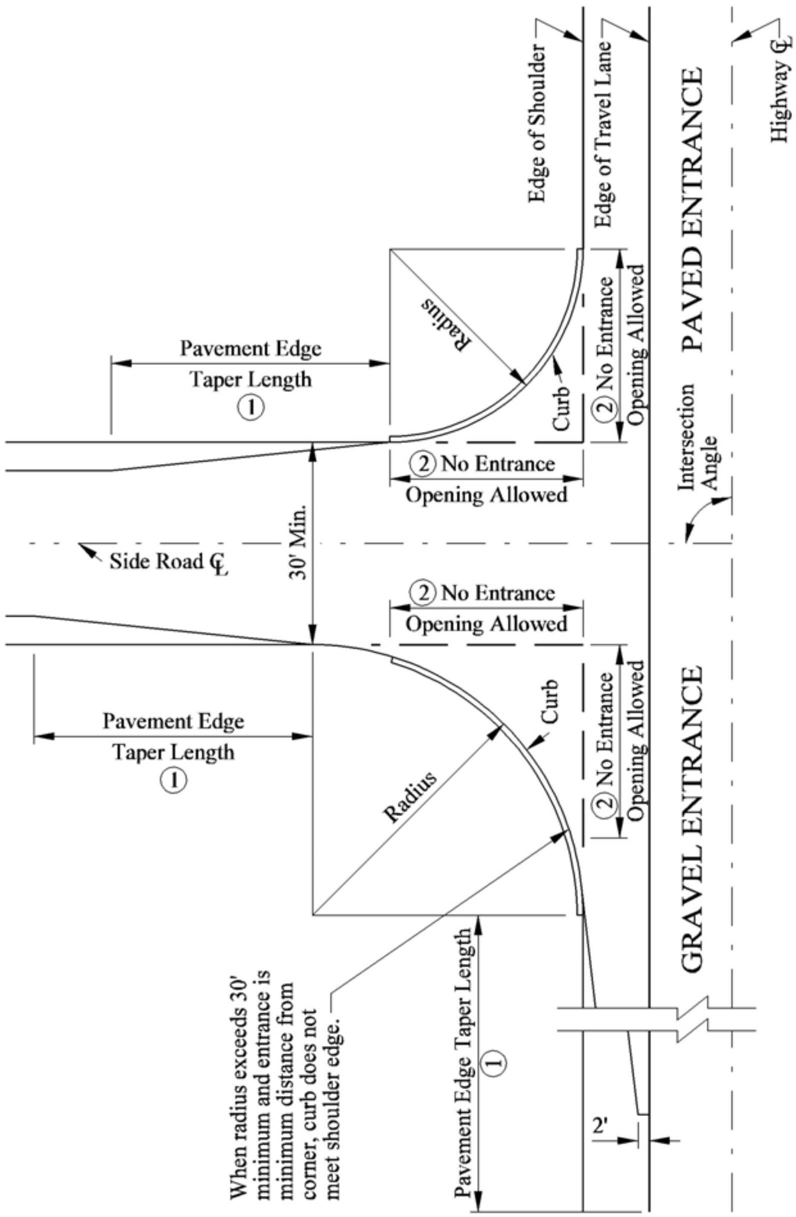
1. Island width to extend within 1'-0" of right-of-way line, if practical.
2. Island length to be determined by island width and entrance angle. Length will be in multiple of 4. Minimum length will be 12'.
3. Entrance angle should not be less than 45°.
4. This is shoulder width/curb offset. In rural areas, if a 4' or 6' shoulder is on the mainline, this should be increased by 2' at the island. An 8' or 10' shoulder need not be increased.

COMMERCIAL/INDUSTRIAL DOUBLE ENTRANCE ONTO UNCURBED HIGHWAY
(Paved Shoulders)

Figure 8-34

COMMERCIAL/INDUSTRIAL DOUBLE ENTRANCES ONTO UNCURBED HIGHWAY
(Paved Shoulders)

Figure 8-34



Notes:

① Where there are gravel shoulders, pavement edge should be tapered for a minimum distance of 10 x the shoulder width.

② This dimension will be determined as follows:

Intersection	*Distance*
90°	30'
85°	33'
80°	36'
75°	39'
70°	43'
65°	47'
60°	52'

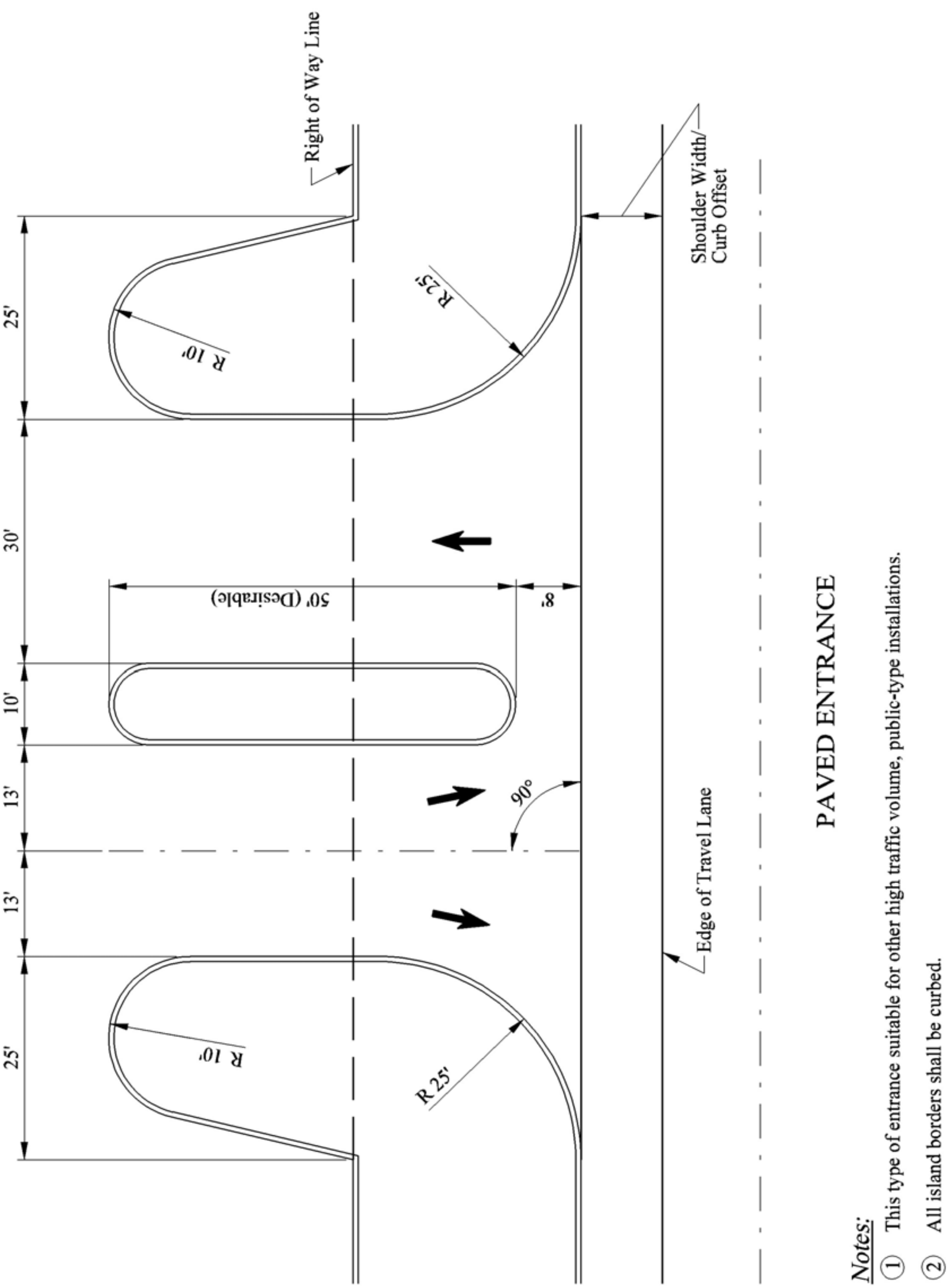
In addition, entrances on the approach side of stop or signal control should not be located within the storage length (L_S). See Section 8-4.

CORNER LOT ENTRANCE ONTO RURAL HIGHWAY

Figure 8-35

CORNER LOT ENTRANCE ONTO RURAL HIGHWAY

Figure 8-35

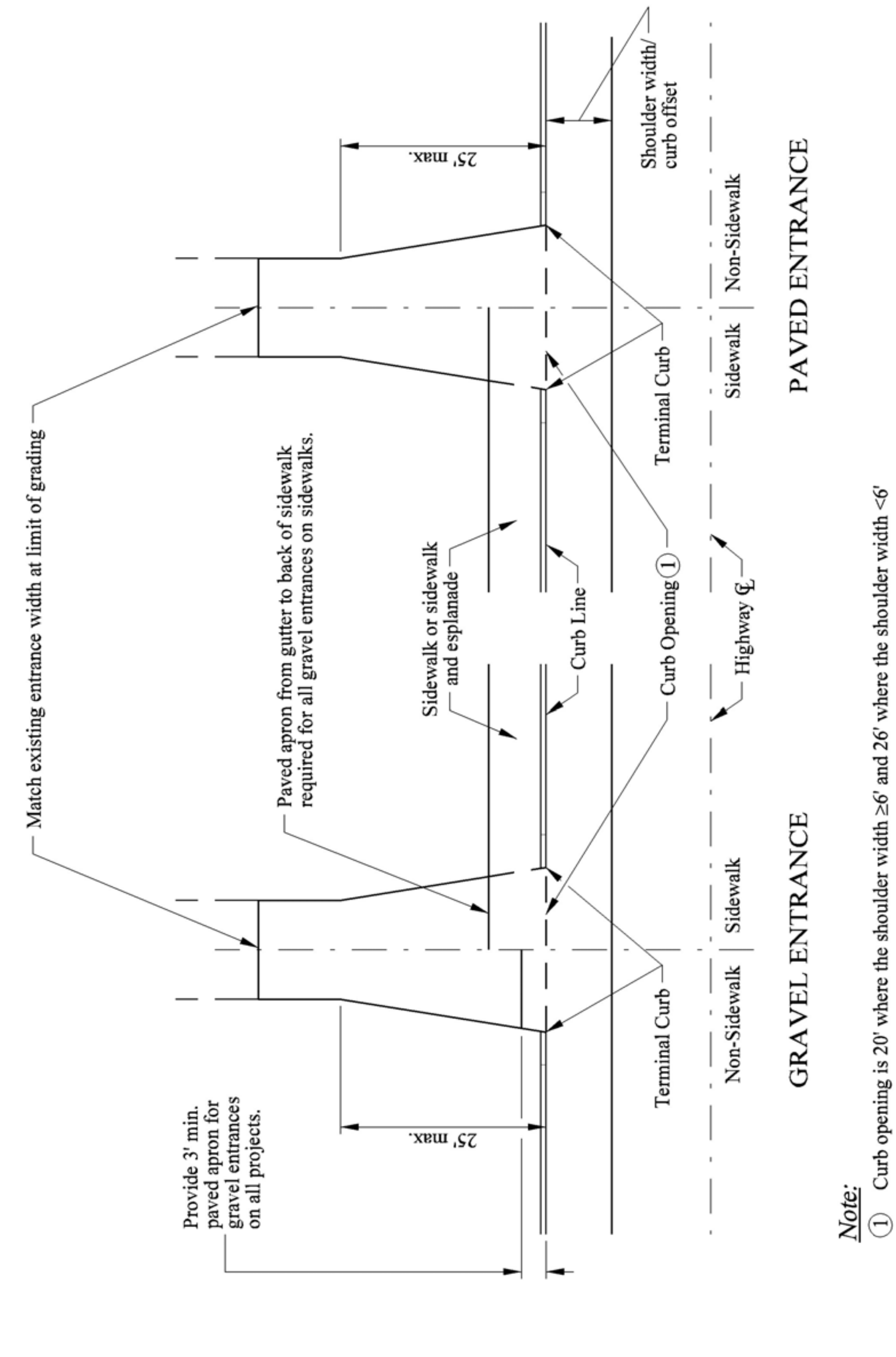


SHOPPING CENTER ENTRANCE ONTO HIGHWAY
(Paved Shoulders)

Figure 8-36

SHOPPING CENTER ENTRANCE ONTO HIGHWAY
(Paved Shoulders)

Figure 8-36

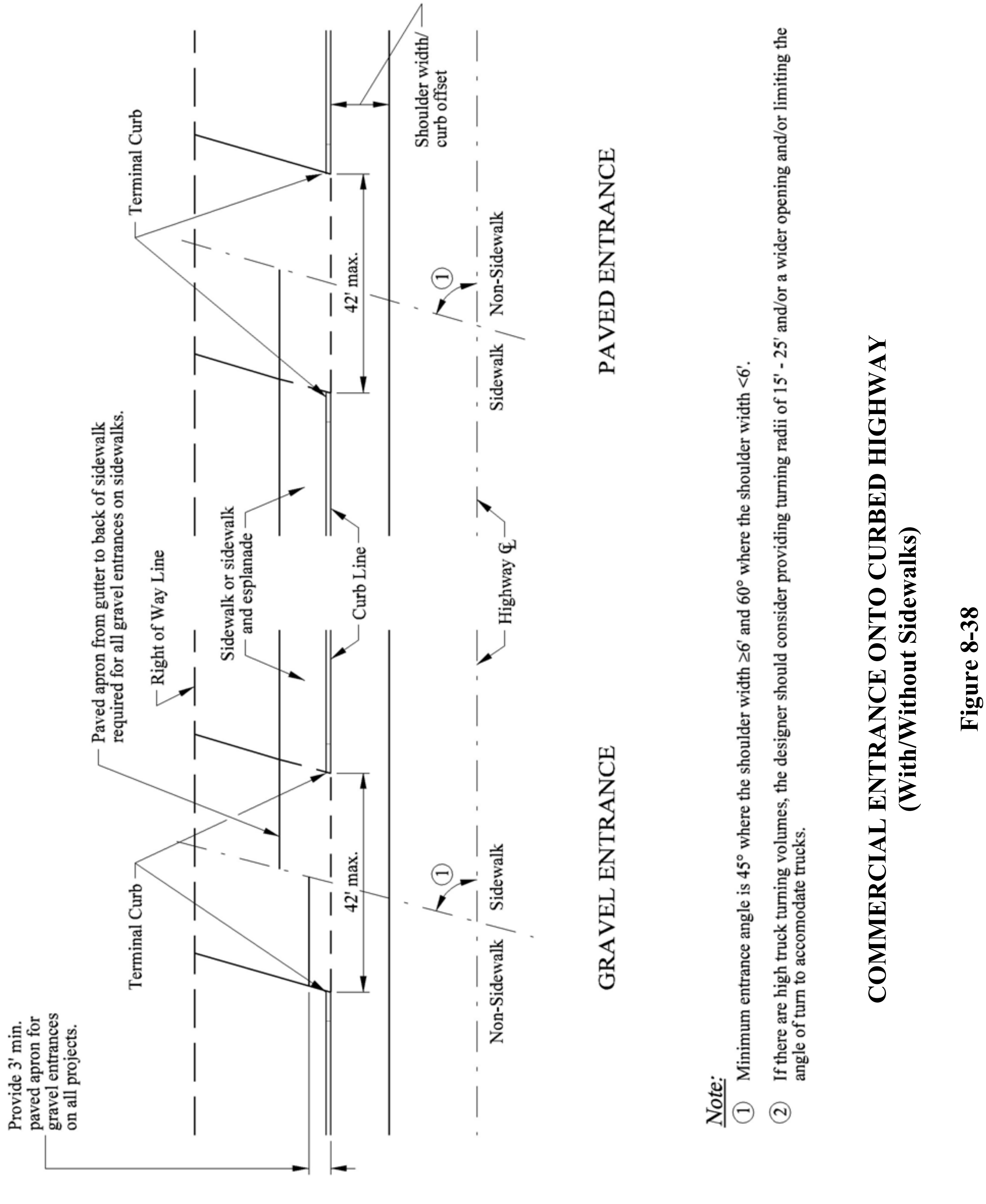


RESIDENTIAL ENTRANCE ONTO CURBED HIGHWAY
(With/Without Sidewalks)

Figure 8-37

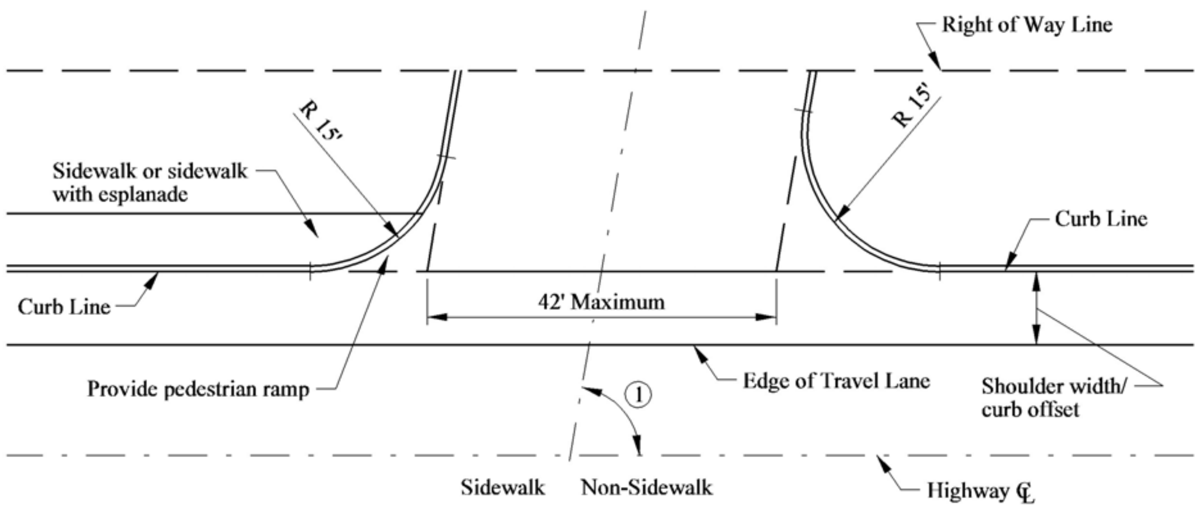
RESIDENTIAL ENTRANCE ONTO CURBED HIGHWAY
(With/Without Sidewalks)

Figure 8-37



COMMERCIAL/INDUSTRIAL ENTRANCE ONTO CURBED HIGHWAY
(With/Without Sidewalks)

Figure 8-38



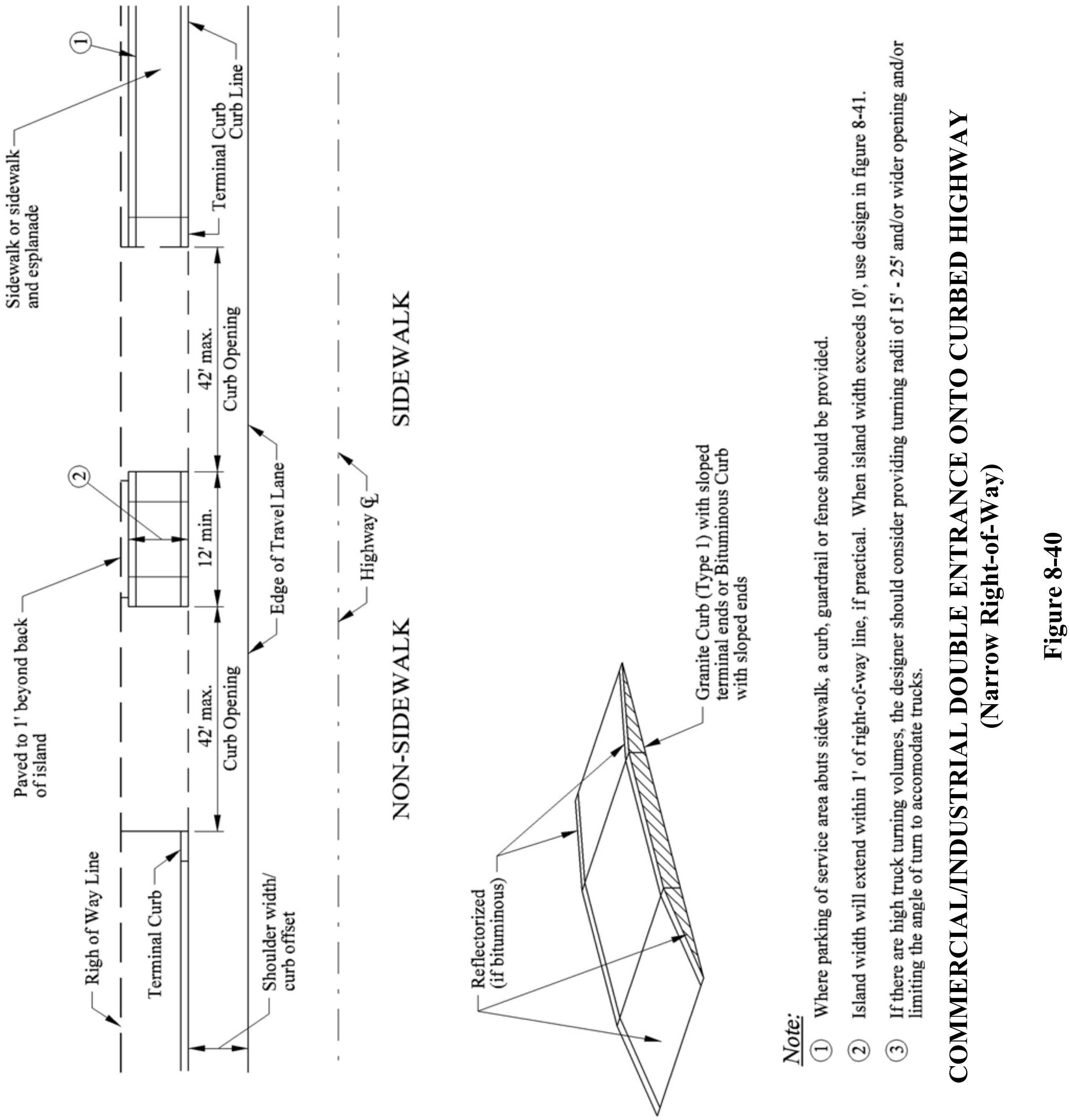
PAVED ENTRANCE

Note:

① Minimum entrance angle is 45° where the shoulder width ≥6' and 60° where the shoulder width <6'

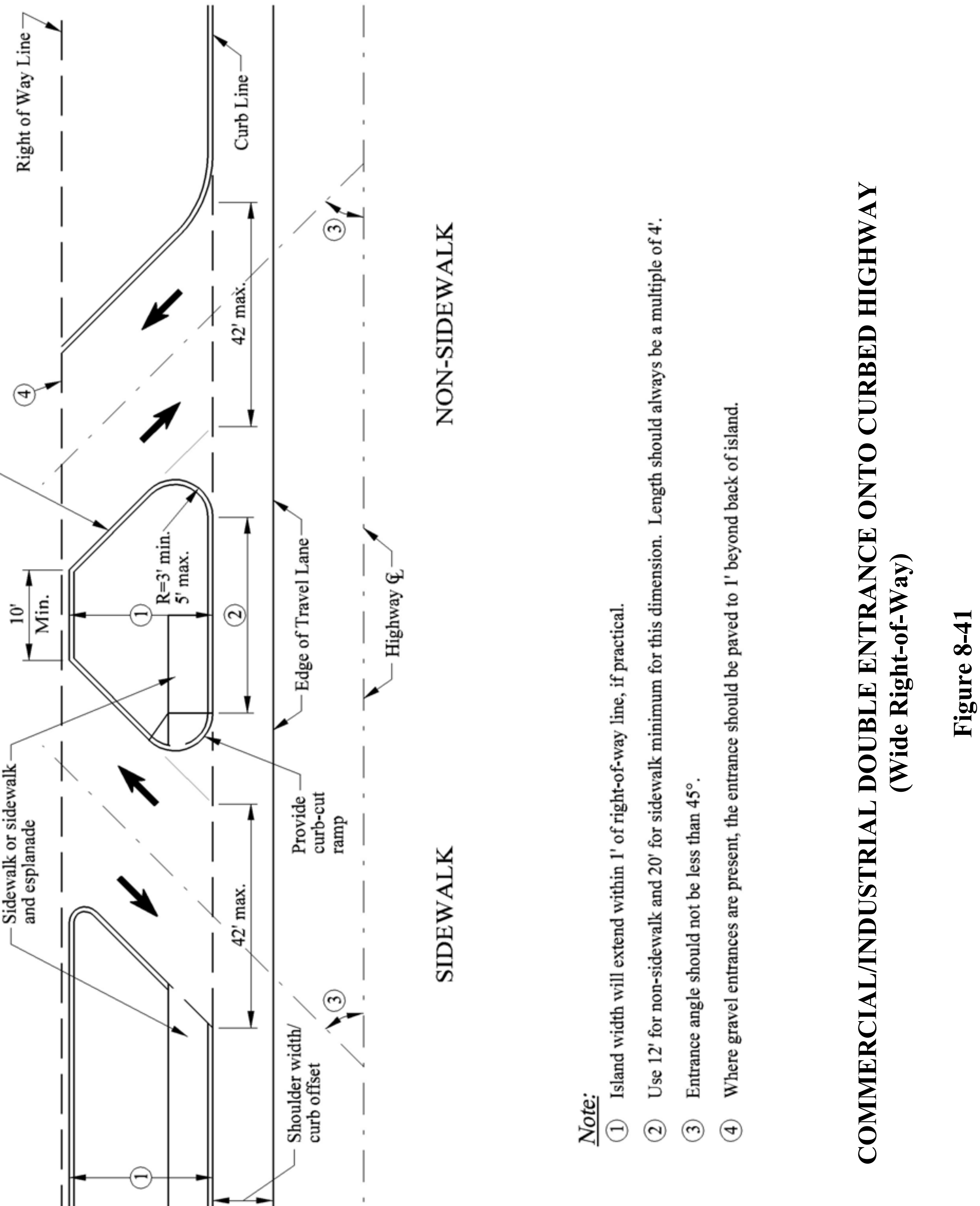
COMMERCIAL/INDUSTRIAL ENTRANCE ONTO CURBED HIGHWAY
(Curbed Entrance)

Figure 8-39



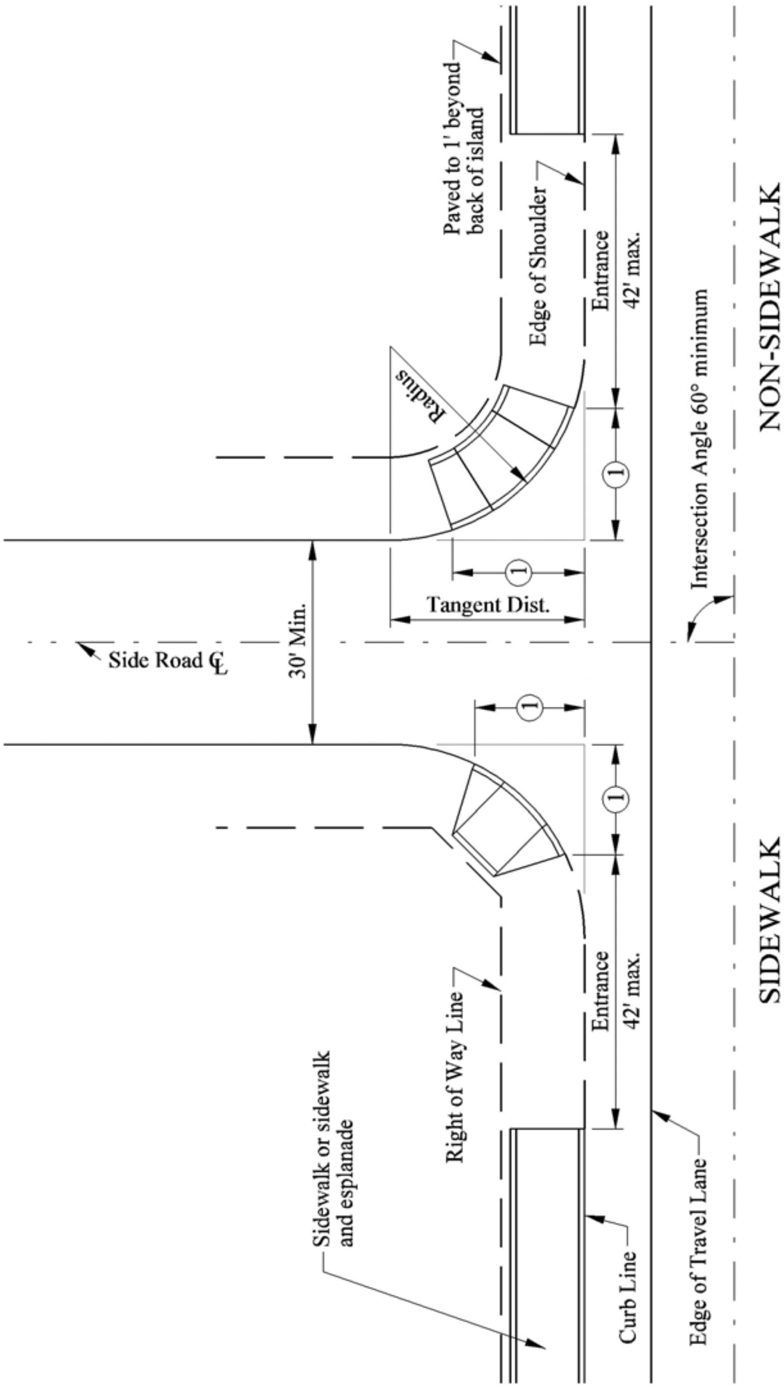
COMMERCIAL/INDUSTRIAL DOUBLE ENTRANCE ONTO CURBED HIGHWAY
(Narrow Right-of-Way)

Figure 8-40



COMMERCIAL/INDUSTRIAL DOUBLE ENTRANCES ONTO CURBED HIGHWAY
(Wide Right-of-Way)

Figure 8-41



Notes:

(1) No curb opening allowed in this area. This dimension will be determined as follows:

Intersection	*Distance*
90°	15'
85°	16'
80°	18'
75°	20'
70°	21'
65°	24'
60°	26'

These distances apply where radius is ≤25'. Where radius is >25', the distance will be the Tangent Distance minus 10'. In addition, entrances on the approach side of stop or signal control should not be located within the storage length (L_S). See Section 8-4.

CORNER LOT ENTRANCE ONTO URBAN HIGHWAY
(Narrow Right-of-Way)

Figure 8-42

CORNER LOT ENTRANCE ONTO URBAN HIGHWAY
(Narrow Right-of-Way)

Figure 8-42

8-9 ALIGNMENT / PROFILE

8-9.01 Alignment

The angle of intersection should be within 30 degrees of a 90-degree intersection. Skewed intersections beyond 30 degrees increase the travel distance across the major highway, adversely affect sight distance and complicate the designs for turning movements. If the angle of intersection is not within 30 degrees of a right angle, the intersection should be realigned to 90 degrees, if practical.

8-9.02 Profile

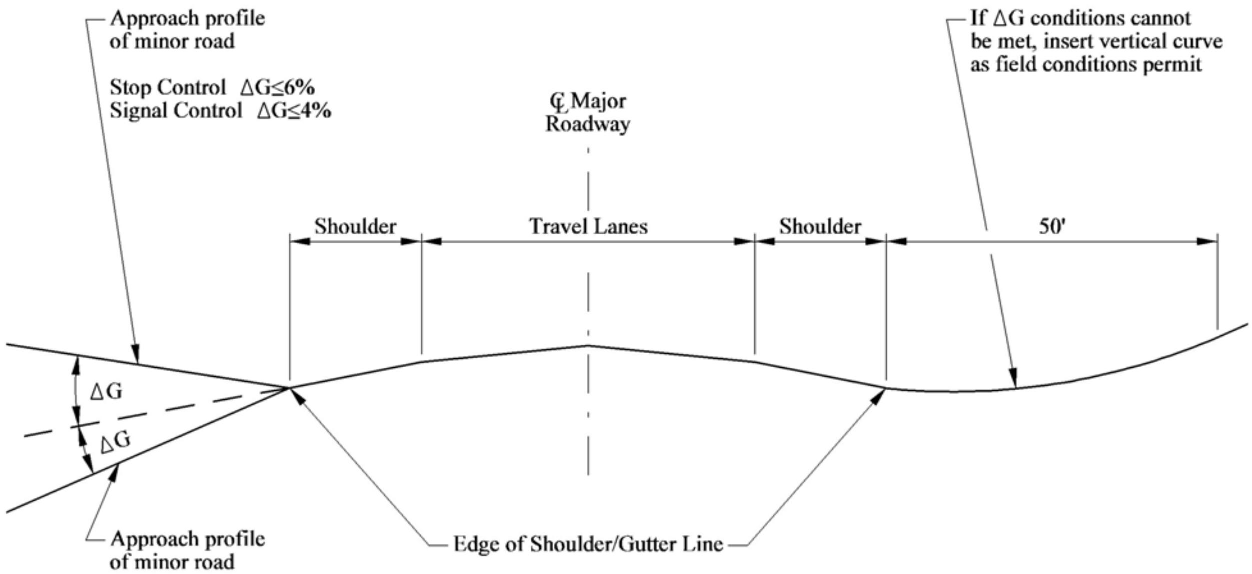
Figure 8-43 illustrates profile considerations. The following will apply:

1. ***Approaching Gradient***. The area where vehicles may store on the leg of an intersection should be as flat as practical. The grade on this landing area (or storage platform) should not exceed 2%, if practical.

2. ***Stop-Controlled***. The profile and cross section of the major road will normally be maintained through the intersection. The cross section of the stop-controlled road will be transitioned (or warped) to match the major road. The change in gradient on the stop-controlled leg at its entrance into the intersection should not exceed 6%. If it does, the designer should insert a vertical curve approximately 50 feet long to transition from the grade on the minor road to meet the cross slope on the major road.

3. ***Signal-Controlled***. The most desirable option will be to transition all approach legs into a plane section through the intersection. This will ensure that the vehicles that pass through the intersection will not "bottom out." This may be especially appropriate for arterial/arterial intersections. If this option is not practical, the designer should transition one road to meet the profile and cross section of the other road. The change in gradient on the transitioned leg at its entrance into the intersection should not exceed 4%. If it does, the designer should insert a vertical curve approximately 50 feet long to transition from the grade on the minor road to meet the cross slope on the major road.

4. ***Drainage***. The profile and transitions at all intersections should be evaluated for their impact on drainage



Note:

1. At signalized intersections, the most desirable option will be to transition all approach legs into a plane section through the intersection.
2. Pavement transitions on the minor road from normal crown to match the slope of the major road should occur over a distance of 25'-50'.
3. If practical, the gradient of the approaching roadway where vehicles may store should not exceed 2%.
4. Actual field conditions will determine the final design.

PROFILES OF INTERSECTING ROADS

Figure 8-43

8-10 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, AASHTO, 2001.

2. *Highway Capacity Manual*, Special Report No. 209, Transportation Research Board.

3. *Manual on Uniform Traffic Control Devices*, National Advisory Committee on Uniform Traffic Control Devices.

4. Highway Research Board, Special Report No. 74, "Channelization," National Research Council, 1962.

5. Report No. FHWA-RD-76-86, "Technical Guidelines for the Control of Direct Access to Arterial Highways," August, 1975.

6. NCHRP 93, "Guidelines for Medial and Marginal Access Control on Major Roadways," Highway Research Board, 1970.

7. FHWA Course Notebook, "Safety Design and Operational Practices for Streets and Highways," Texas Transportation Institute, 1978.

7. "Volume Warrants for Left-Turn Storage Lanes at Unsignalized Grade Intersections," M.D. Harmelink, Highway Research Record 211, 1967.

9. Technical Council Information Report, "Design and Use of Two-Way Left-Turn Lanes," Institute of Transportation Engineers, ITE Journal, February, 1981.

10. Technical Council Informational Report, "Design Criteria for Left-turn Channelization," Institute of Transportation Engineers, ITE Journal, February, 1981.

11. "Guidelines for Treatment of Right-Turn Movements on Rural Roads," Transportation Research Record 855, 1982.

12. "Development of Guidelines for the Application of Continuous Two-Way Left-Turn Median Lanes," Final Report - EES470, Zoltan Nemeth, Ohio State University, July, 1976.

13. Technical Council Informational Report, "Effectiveness of Median Storage and Acceleration Lanes for Left-Turning Vehicles," Institute of Transportation Engineers, ITE Journal, March, 1985.

14. Institute of Transportation Engineers Recommended Practice, "Guidelines for Driveway Design and Location," Institute of Transportation Engineers, 1985.

15. NCHRP 279, "Intersection Channelization Design Guide," Transportation Research Board, November, 1985.

16. NCHRP 270, "Parameters Affecting Stopping Sight Distance," Transportation Research Board, June, 1984.

CHAPTER NINE

INTERCHANGES

Volume I

- Highway Design Guide –

National Standards

<u>December 2004</u>

Chapter Nine

TABLE OF CONTENTS

Page

Chapter Nine

INTERCHANGES

9-1 WARRANTS

An interchange is a system of interconnecting roadways in conjunction with one or more grade separations that provide for the movement of traffic between roadways on different levels. The following lists several general warrants for an interchange:

1. ***Design Designation***. Once a controlled access facility has been designated on the major road, an interchange may be warranted for a crossing road based on the anticipated demand for access to the minor road.

2. ***Traffic Volumes***. An interchange may be warranted to accommodate the traffic volumes at the selected level of service and the traffic distribution pattern of an at-grade intersection.

3. ***Road-User Benefits***. An interchange may be warranted where the road user costs (e.g., travel time, accidents) are significantly reduced when compared to at-grade intersections.

4. ***Site Topography***. The topography at some locations may allow an interchange at less cost than an at-grade intersection.

If an interchange is warranted for any of the listed reasons, interchange spacing is an additional consideration in the decision-making process. As a general rule, interchanges should be no closer than one mile apart in urban areas and two miles apart in rural areas. Closer interchange spacings may be acceptable if a special design can be implemented (e.g., collector-distributor roads) so that the freeway elements (e.g., weaving areas, freeway/ramp terminals) can operate at an acceptable level of service.

9-2 INTERCHANGE TYPES

Each interchange must be designed to fit the individual site characteristics. The final design may be a minor or major modification of one of the basic types, or it may be a combination of two or more interchange types. In addition to interchange types, the following basic definitions apply to interchange designation:

1. ***Systems Interchanges***. These are interchanges between two fully access-controlled highways (freeways).

2. ***Service Interchanges***. These are interchanges where one or both of the intersecting highways is not a fully access-controlled facility.

9-2.01 Three-Leg

Three-leg interchanges are also designated as T- or Y-interchanges. Figure 9-1 illustrates examples of three-leg interchanges with several methods of providing the turning movements. The trumpet type (A) provides three turning movements with direct or semi-direct ramps and one movement by a loop ramp. In general, the semi-direct ramp should favor the heavier left-turn movement and the loop the lighter volume. Where both left-turning movements are fairly heavy, the design in (C) should be used. A fully directional interchange (B) is appropriate when all turning volumes are heavy, or the intersection is between two access-controlled highways.

9-2.02 Diamond

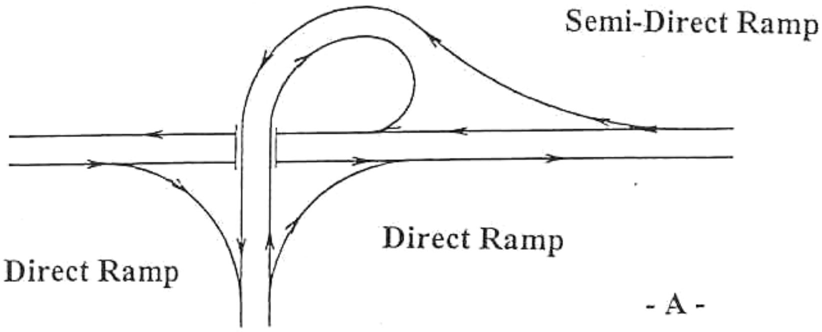
The diamond interchange is often the best choice where the intersecting road is not access controlled. Figure 9-2 illustrates a schematic of the diamond. Its advantages include:

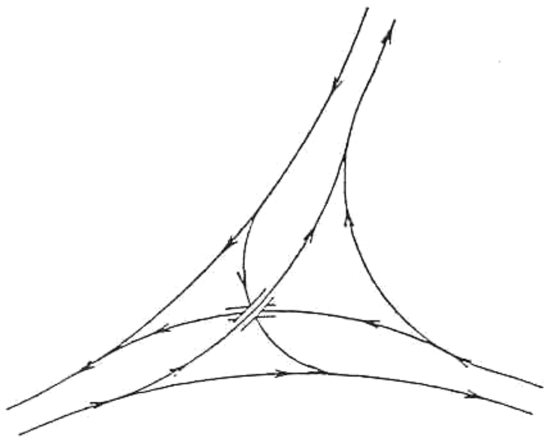
1. Adequate sight distance can usually be provided, and the operational maneuvers are normally uncomplicated.

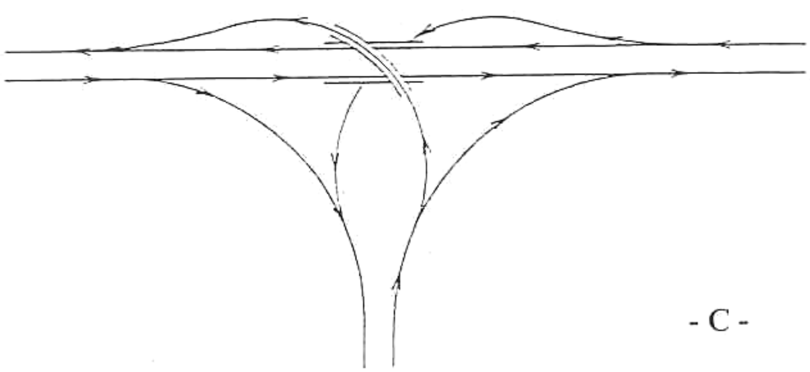
2. Less right-of-way is required.

3. All exits from the mainline are made before reaching the structure.

4. Left-turning maneuvers require less travel distance

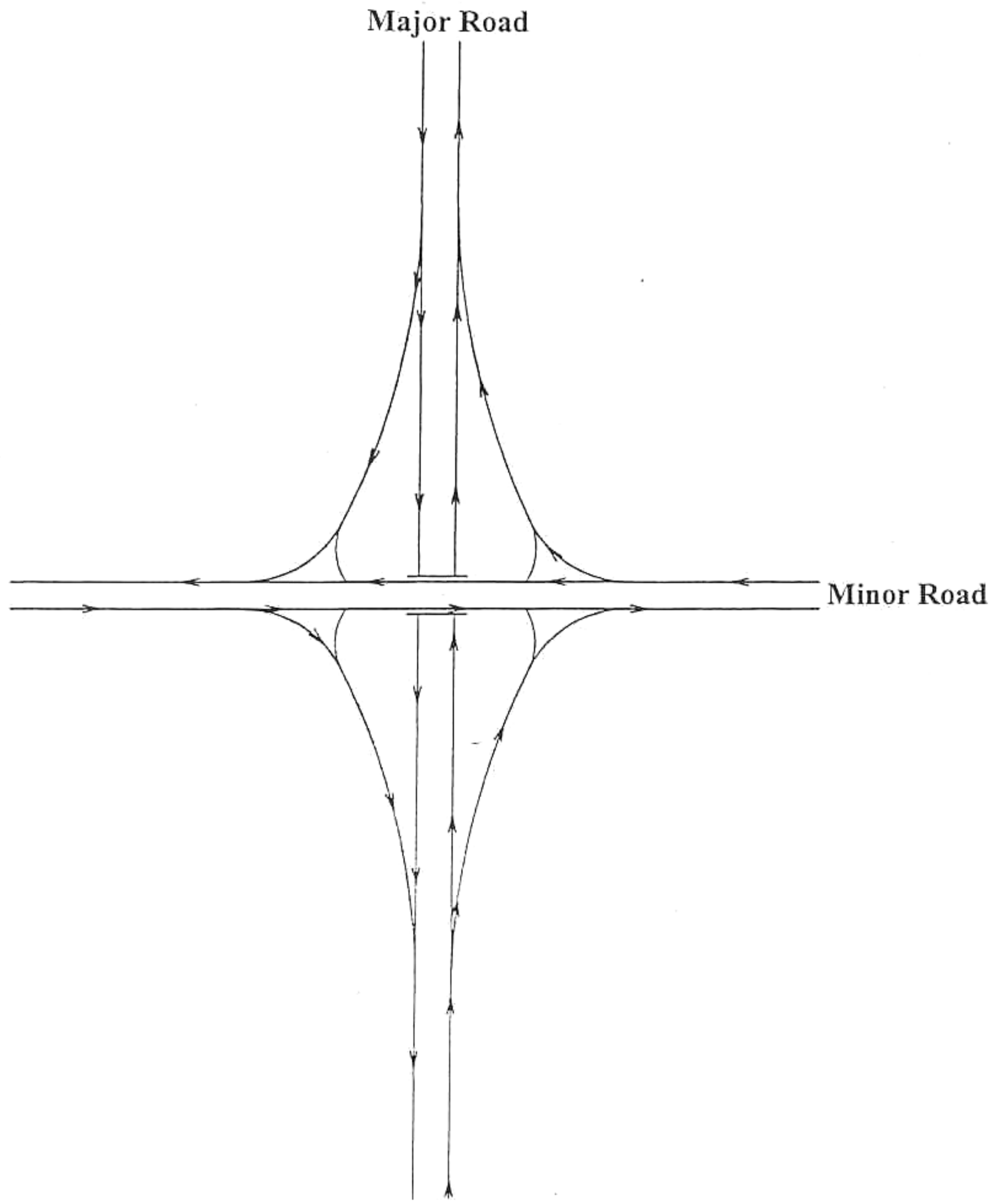






TYPICAL THREE-LEG INTERCHANGES

Figure 9-1



TYPICAL DIAMOND INTERCHANGE

Figure 9-2

5. The diamond interchange allows relatively easy modifications to provide greater ramp capacity, if needed in the future.

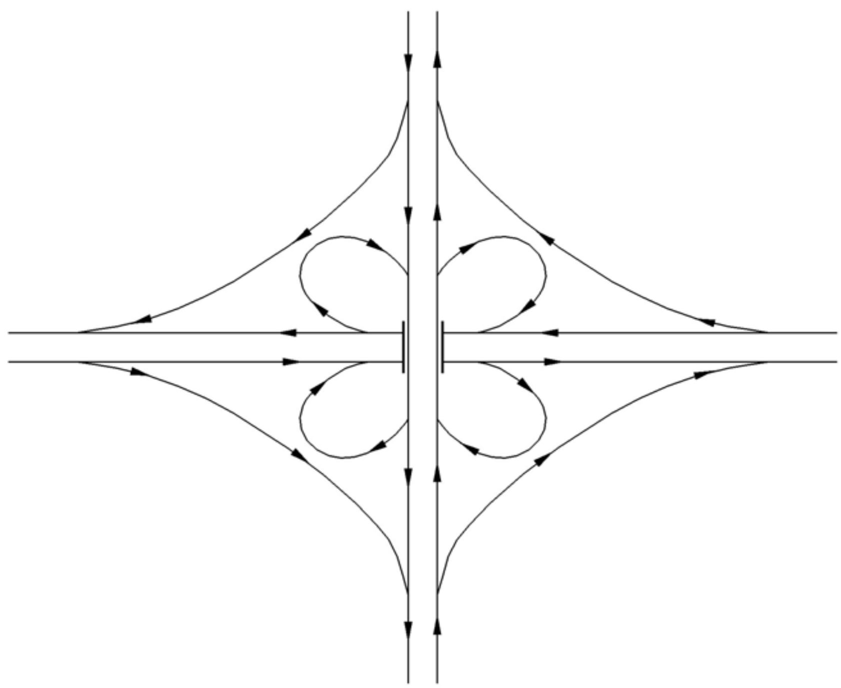
6. Their common usage has resulted in a high degree of driver familiarity.

The primary disadvantages of a diamond interchange are the potential operational problems with the two at-grade intersections at the minor road and the potential for wrong-way entry onto the ramps from the minor road.

9-2.03 Cloverleafs

Cloverleaf interchanges are used at 4-leg intersections and employ loop ramps to accommodate left turn movements. Full cloverleaf interchanges are those with loops in all four quadrants; all others are partial cloverleafs.

Where two access controlled and divided highways intersect, a full cloverleaf is the minimum type design that will suffice (Figure 9-3). However, these interchanges introduce several operational

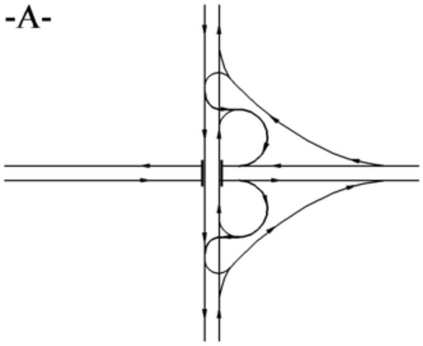


FULL CLOVERLEAF INTERCHANGE

Figure 9-3

features such as the double exits and entrances from the mainline, the weaving between entering and exiting vehicles with the mainline traffic, and the lengthy travel time and distance for left-turning

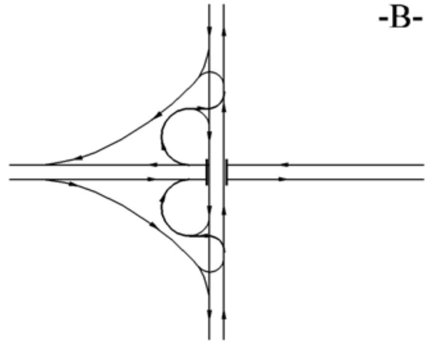
-A-



ON BOTH SIDES OF MAJOR ROAD

Left Turns: None on Major Road
Four on Minor Road

-B-

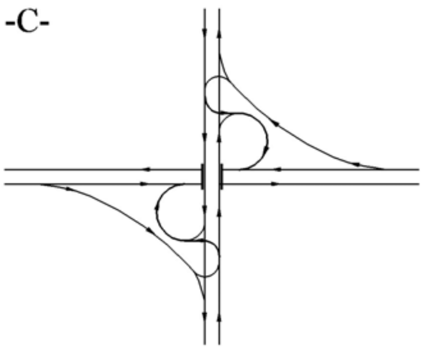


ON BOTH SIDES OF MAJOR ROAD

Left Turns: None on Major Road
Four on Minor Road

TWO QUADRANTS ADJACENT

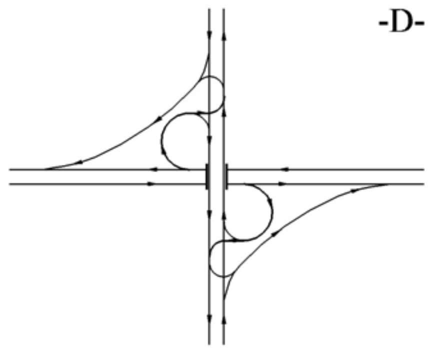
-C-



MAJOR ROAD EXITS ON NEAR SIDE

Left Turns: None on Major Road
Four on Minor Road

-D-

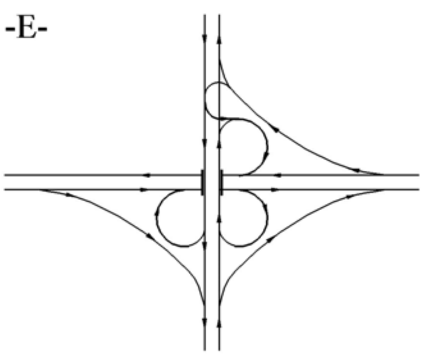


MAJOR ROAD EXITS ON FAR SIDE

Left Turns: None on Major Road
Four on Minor Road

TWO QUADRANTS DIAGONALLY OPPOSITE

-E-

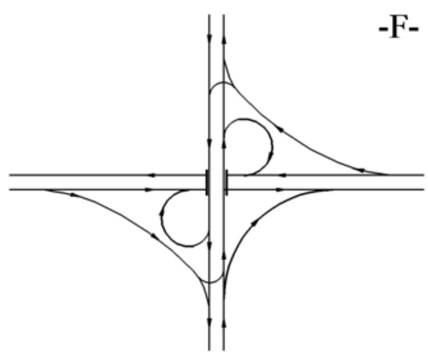


TWO MAJOR ROAD EXITS ON NEAR SIDE

Left Turns: None on Major Road
Two on Minor Road

THREE QUADRANTS

-F-



MAJOR ROAD EXITS ON NEAR SIDE

Left Turns: None on Major Road
Two on Minor Road

FOUR QUADRANTS

PARTIAL CLOVERLEAF ARRANGEMENTS

Figure 9-4

9-2.05 Directional and Semi-Directional

The following definitions apply to directional and semi-directional interchanges:

1. ***Directional Interchange.*** An interchange where one or more turning movements are provided by direct connection.

2. ***Semi-Directional Interchange.*** An interchange where one or more left-turning movements are provided by semi-direct connections, even if the minor left-turn movements are accommodated by loops, and where there are no directional ramps.

3. ***Fully Directional Interchange.*** An interchange where all turning movements are accommodated by direct connections.

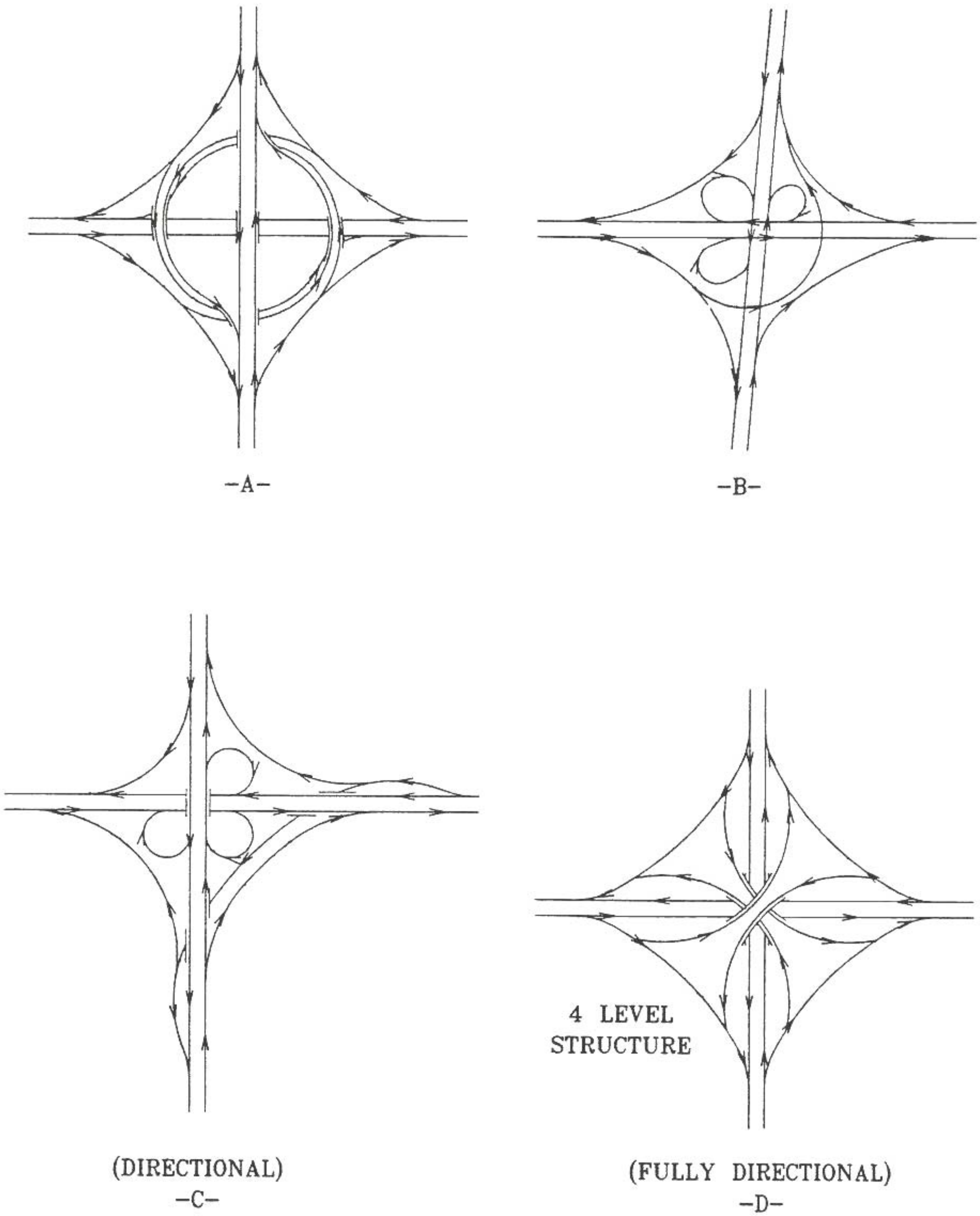
The following definitions apply to directional and semi-directional ramps:

1. ***Direct Ramp Connection***. A ramp that does not deviate greatly from the intended direction of travel (as does a loop, for example).

2. ***Semi-Direct Ramp Connection***. A ramp that is indirect in alignment yet more direct than loops.

Direct or semi-direct connections are used for heavy left-turn movements to reduce travel distance, increase speed and capacity, and eliminate weaving. These type connections allow an interchange to operate at a better level of service than is possible with loop ramps. Figure 9-5 illustrates three semi-directional and directional interchanges. Note that none of these designs has left-hand exits or entrances from the mainline, which is very desirable. Left-hand exits and entrances violate driver expectancy and should not be used, if practical.

Directional or semi-directional interchanges are most often warranted in urban areas at freeway-to-freeway or freeway-to-arterial intersections. They require less right-of-way than cloverleaf interchanges. A fully directional interchange provides the highest possible capacity and level of service, but it is very costly to build because of the multiple-level structure required.



DIRECTIONAL INTERCHANGES

Figure 9-5

9-3 FREEWAY/RAMP JUNCTIONS

9-3.01 Exits

Types

Exit ramps can be the taper type or the parallel lane type. In general, a properly designed taper exit will operate better than one with a parallel lane. However, at restrictive sites where a taper design cannot provide the needed deceleration length for sharp curvature or where the freeway mainline is curving to the left or where restrictive geometrics exist (e.g., inadequate sight distance), a parallel lane may be the best selection; a parallel lane exit may also be needed for capacity.

Figures 9-6 and 9-7 provide the typical designs for taper and parallel lane exit ramps. The following discussion provides specific information on the design elements for each exit ramp.

Deceleration Length

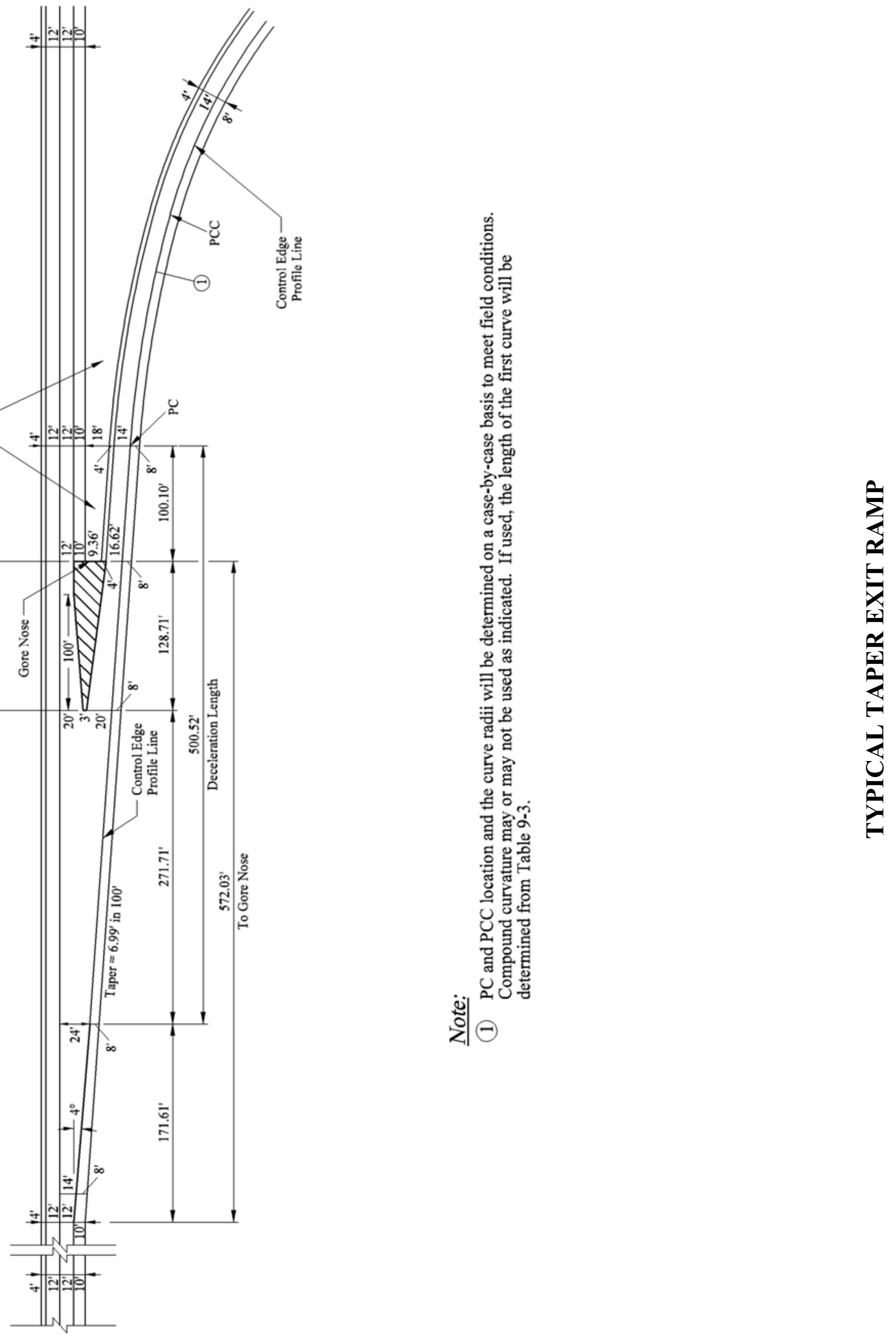
All deceleration should occur within the full width (12 feet) of the exit lane. The necessary length for deceleration will depend upon the design speed of the mainline and the design speed of the first horizontal curve on the exit ramp.

Table 9-1 provides the deceleration distance for various combinations of highway design speed and exit curve design speed. The following steps should be used to determine the length of a deceleration lane for freeway exit ramps:

Step 1: Determine the mainline design speed and the design speed of the first horizontal curve on the exit ramp.

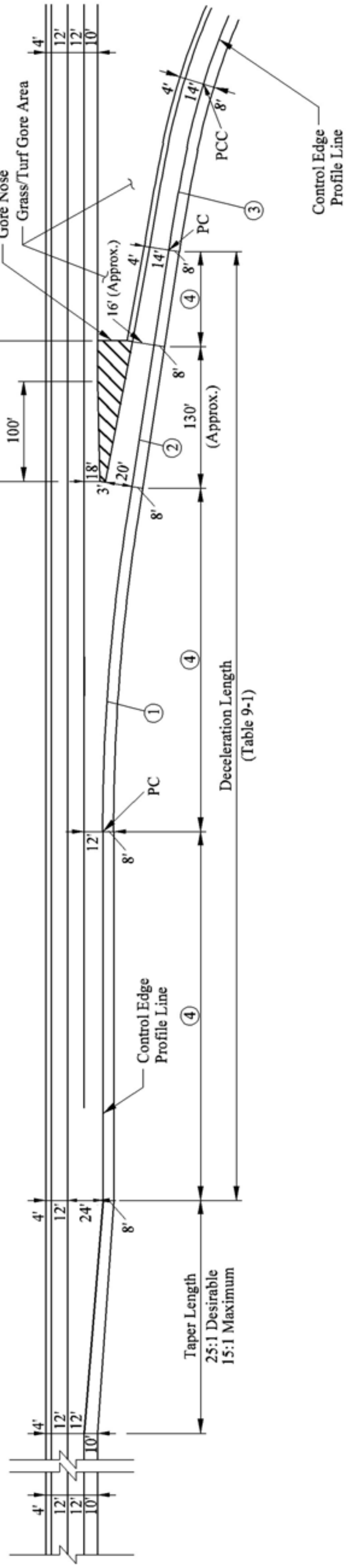
Step 2: Enter Table 9-1 with the two design speeds to determine the recommended length for deceleration. This value will apply from the point where the taper exit or parallel lane becomes 12 feet to the PC of the first horizontal curve. Greater distances should be provided if practical. Note that the Department's typical taper exit design in Figure 9-6 will provide the necessary deceleration length for all mainline design speeds up to 70 mph and design speeds for exit ramp curves for 35 mph or higher.

Step 3: If the deceleration will occur on a grade of three percent or more, the necessary length for deceleration should be adjusted according to the criteria in Table 9-2.



TYPICAL TAPER EXIT RAMP

Figure 9-6



TYPICAL PARALLEL LANE EXIT RAMP

Figure 9-7

Note:

1. The location and length of this curve will be determined on a case-by-case basis to meet field conditions. To not impede vehicular deceleration, the radius of this curve should be approximately 1500 feet or more. If the radius is sharper than this, see Note #4.

2. The use of a taper and, if used, the rate of the taper will be determined on a case-by-case basis to meet field conditions.

3. PC and PCC location and the curve radii will be determined on a case-by-case basis to meet field conditions. Compound curvature may or may not be used as indicated. If used, the length of the first curve will be determined from Table 9-3.

4. These dimensions will be determined on a case-by-case basis to meet field conditions. If the radius of the curve in Note #1 is sharper than 1500 feet, it will be necessary to provide an adequate deceleration length for the tangent portion of the full-width parallel deceleration lane. Use Table 9-1 and the design speeds of the mainline and curve to determine the necessary length.

TYPICAL PARALLEL LANE EXIT RAMP

Figure 9-7

Major Highway Design Speed (mph)	L = Deceleration Length (ft)								
	For Design Speed of First Horizontal Curve on Ramp (mph)								
	0 (Stop)	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*50*
30	235	200	170	140	-	-	-	-	-
40	320	295	265	235	185	155	-	-	-
50	435	405	385	355	315	285	225	175	-
60	530	500	480	460	430	405	350	300	240
65	570	540	520	500	470	440	390	340	280
70	615	590	570	550	520	490	440	390	340

MINIMUM LENGTH FOR DECELERATION
(Level Grade)

Table 9-1

Direction of Grade	Ratio of Deceleration Length on Grade to Length on Level			
	< 3%	*3% ≤ G < 5%*	*5% ≤ G < 7%*	*G ≥ 7%*
Upgrade	1.0	0.9	0.8	0.7
Downgrade	1.0	1.2	1.35	1.5

Notes:

1. Table applies to all highway design speeds.

2. The "grade" in the table is the average grade over the distance used for measuring the length of the deceleration.

GRADE ADJUSTMENTS FOR DECELERATION

Table 9-2

Step 4: Where the first horizontal curve is compounded, determine the necessary distance between the PC & PCC from Table 9-3. See Example 2.

Radius of Sharper Arc (R_2) (ft)	Length of Adjoining Circular Arc (R_1) (ft)*
100	60
150	70
200	90
250	120
300	140
400	180
$\geq$ 500	200

* *These criteria for R_1 apply to a curve which precedes the "Radius of Arc (R_2)" ($R_1 \leq 2.0\ R_2$). For a 3-centered curvature arrangement, the criteria also apply to the length of R_2 which precedes R_3 ($R_3 \leq 2.0\ R_2$).*

LENGTHS OF COMPOUND CURVES
(Freeway/Ramp Junctions)

Table 9-3

* * * * * * * * * *

Example 1

Given:	Highway Mainline (Design Speed)	-	70 mph
	First Horizontal Curve on Ramp (Design Speed)	-	40 mph
	Average Grade	-	5% downgrade

Problem: Determine necessary length for deceleration.

Solution: Table 9-1 yields a minimum deceleration length of 440 ft on the level. According to Table 9-2, this should be increased by 1.35.

Therefore: $L = (440)\ (1.35)$

$L = 594$ ft

A 594-ft deceleration length should be provided from the point at which a taper exit becomes 12 feet <u>or</u> for the full width of the parallel lane to the PC of the first horizontal curve.

<u>Example 2</u>

Given: The first horizontal curve on an exit ramp is a 3-centered curvature arrangement with the following radii:

$R_1 = 600$ ft

$R_2 = 300$ ft

$R_3 = 600$ ft

Problem: Determine the minimum length of the arc R_1 (from PC to PCC) to allow the vehicle to decelerate from the design speed of R_1 to the design speed of R_2.

Solution: Table 9-3 indicates that, if $R_2 = 300$ ft, the preceding arc should be at least 140 ft to allow safe deceleration. Therefore, the distance between the PC and PCC should be 140 ft or more. Note that, because R_3 is flatter than R_2, deceleration need not be considered in determining the length of arc from the PCC to PT. Figure 9-6 illustrates the 3-centered curvature arrangement.

* * * * * * * * * *

<u>Sight Distance</u>

Decision sight distance should be available for drivers approaching an exit. This sight distance is particularly important for exit loops immediately beyond the structure. Vertical curvature or bridge piers can obstruct the exit points if not carefully designed. When measuring for adequate sight distance, the designer should use a 2.0-ft height of object and should use the gore nose as the point to where decision sight distance should be available. Section 4-1.02 discusses decision sight distance in more detail.

* * * * * * * * *

Example 3

Given: An exit loop is located just beyond a bridge which is on a crest vertical curve. The algebraic difference (A) is 3% for the curve. The facility is a rural freeway with a design speed of 70 mph.

Problem: Determine the necessary length of the vertical curve to provide decision sight distance (DSD) to the exit gore.

Solution: Section 4-1.02 discusses DSD. Based on the DSD criteria and the given information, the following elements will apply to the design of the crest vertical curve:

A = 3%

DSD = 1105 ft (direction change on a rural road at 70 mph)

Height of eye (h_1) = 3.5 ft

Height of object (h_2) = 2.0 ft

The equation for L for the crest vertical curve is:

$$L = \frac{A(DSD)^2}{100(\sqrt{2h_1} + \sqrt{2h_2})^2}$$

$$L = \frac{(3)(1105)^2}{100(\sqrt{(2)(3.5)} + \sqrt{(2)(2.0)})^2}$$

$$L = 1697$$

Therefore, a crest vertical curve with a length of approximately 1700 ft should be provided.

* * * * * * * * * *

Superelevation

The superelevation at an exit ramp junction should be developed to properly transition the driver from the mainline to the curvature at the exit. The principles of superelevation for open highways,

as discussed in Section 5-2.05, should be applied to the exit ramp junction design. The following specific superelevation criteria will apply:

1. ***Rate.*** e_{max} =6.0%. For a given design speed and radius of curve, Table 5-6 will be used to determine the superelevation rate for the first horizontal curve.

2. ***Transition Length***. The minimum superelevation transition length from typical cross slope (2.0%) to "e" will be 100 feet, regardless of the superelevation rate at the PC of the first horizontal curve. The 100-foot distance applies where the mainline is on a tangent or where the mainline is curving in the same direction as the ramp exit. Where the mainline is curving away from the ramp exit and is superelevated, a parallel deceleration lane should normally be used.

3. ***Distribution***. Full superelevation should be reached at the first 50 foot station occurring a minimum distance of 25 feet beyond the PC of the first horizontal curve. The beginning of the transition will occur at least 100 feet in advance of the station where full superelevation is reached.

   Where compound curvature is used at the freeway/ramp exit, the design "e" (for the sharper curve) will be reached at the first 50-foot station occurring a minimum distance of 25 feet beyond the PCC.

4. ***Axis of Rotation***. The axis of rotation will typically be about the line on the right edge of travelway (i.e., the control edge profile line) of the exit ramp. The cross slope of the left and right shoulders will be adjusted during the superelevation transition such that the algebraic difference between the travelway slope and high-side shoulder slope will not exceed 8%.

Cross Slope Rollover

The cross slope rollover is the algebraic difference between the slope of the through lane and the slope of the exit lane, when these two are adjacent to each other (i.e., before the gore begins). The maximum algebraic difference is 5 percent.

Gore Area

1. ***Definition***. The gore area is normally considered to be the paved triangular area between the through lane and the exit lane, plus the graded area, which may extend a considerable distance downstream beyond the gore nose.

2. ***Roadside Hazards***. If practical, the area beyond the gore nose should be free of signs and luminaire supports for approximately 300 feet beyond the gore nose. If supports must be present, they must be yielding or breakaway or shielded by guardrail or a crash cushion. (See Chapter Ten).

3. ***Cross Slope***. The paved triangular gore area between the through lane and exit lane should be safely traversable. If practical, this area should have a uniform slope at a rate which is intermediate between the slope of the through lane and the slope of the exit lane. However, if a drainage inlet is placed within the paved gore, this will not be practical and may, in fact, require two breaks in the cross slope. In this case, the break in pavement cross slope should not exceed 5 percent at any point.

9-3.02 Entrances

Types

Entrance ramps can be either the taper type or the parallel lane type. A taper entrance ramp requires that the entering vehicle accelerate to the merging speed while still on the ramp proper. The taper type entrance should normally be used at sites where:

1. merging volumes are relatively low (i.e., the volumes are well below the capacity of the freeway/ramp junction (LOS B or better));

2. the entering driver has considerable sight distance (preferably decision sight distance based on the ramp design speed) to see upstream to sight the mainline traffic; and

3. sufficient distance is available for vehicular acceleration.

If any of these criteria are not met, the designer should seriously consider the parallel lane type entrance ramp. Figures 9-8 and 9-9 present typical designs for taper and parallel lane entrance ramps. The following discussion provides specific information on the design elements for each ramp.

Acceleration Length

Table 9-4 provides the acceleration distance for various combinations of entrance curve design speed and highway design speed. These lengths apply to the full width (12 feet) of the entrance lane; taper lengths are in addition to these values. The following steps should be used to determine the

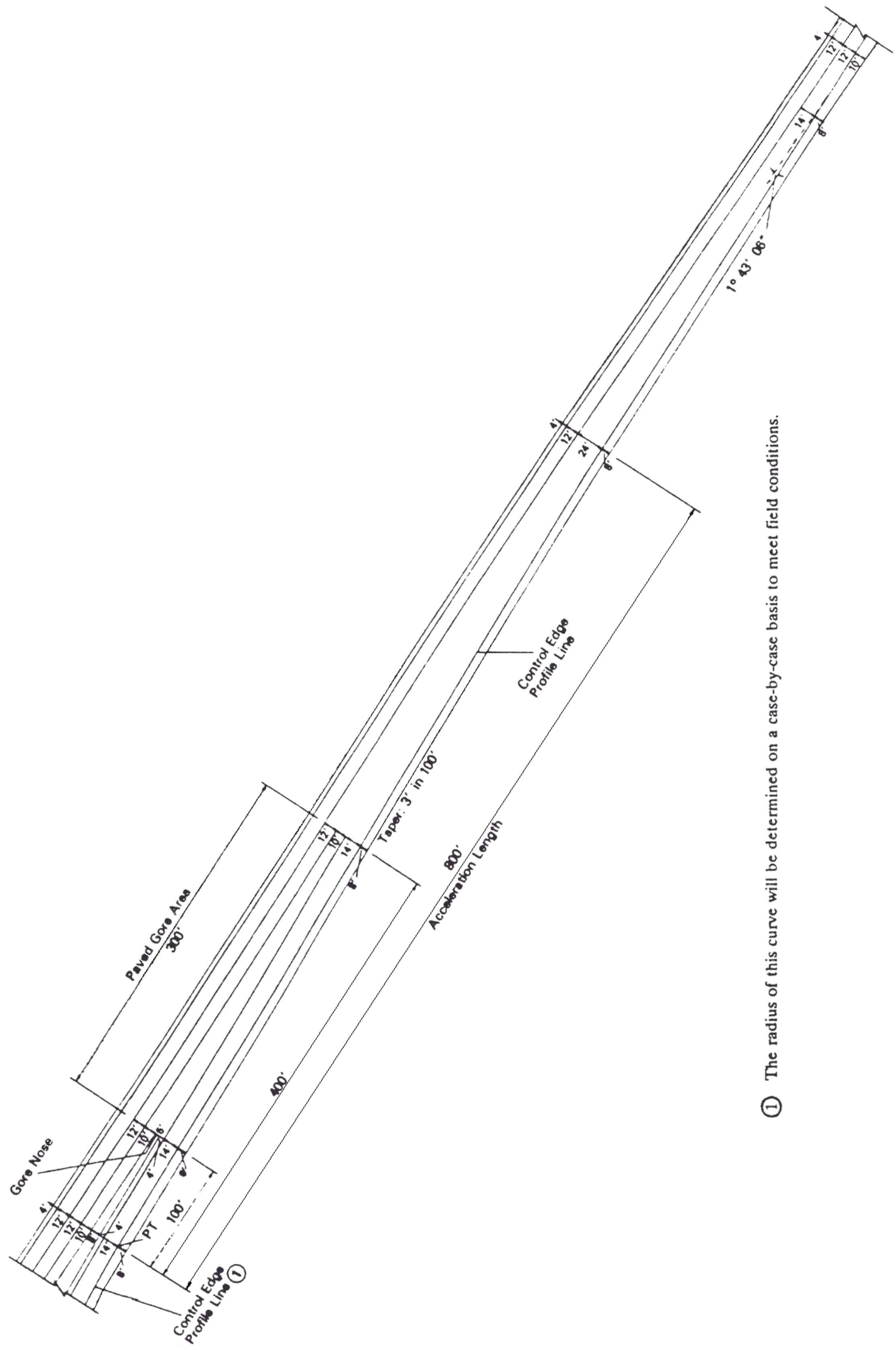
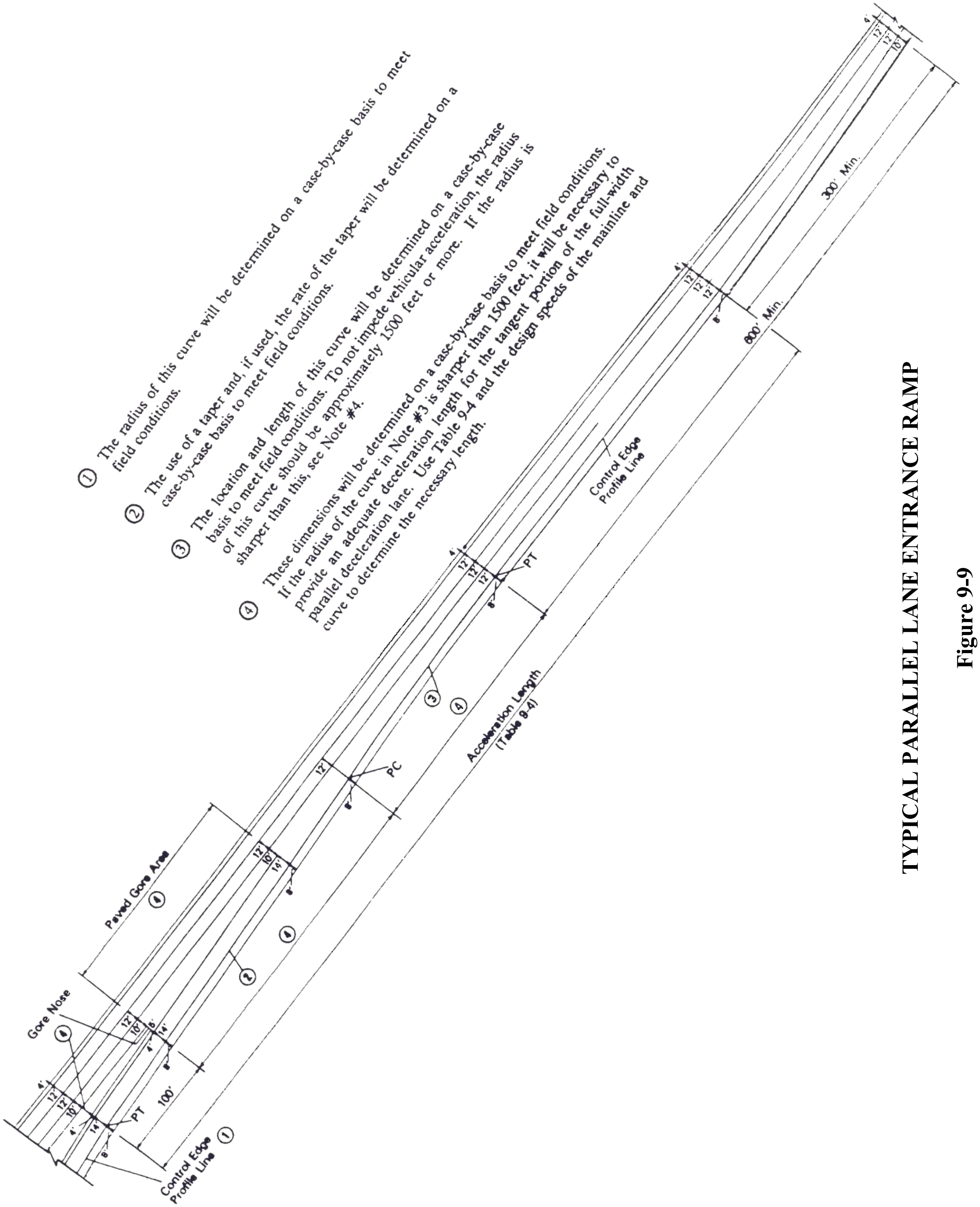


Figure 9-8



TYPICAL PARALLEL LANE ENTRANCE RAMP

Figure 9-9

Major Highway Design Speed (mph)	L = Acceleration Length (ft) For Design Speed of Last Horizontal Curve on Ramp (mph)								
	0 (Stop)	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*50*
30	180	140	-	-	-	-	-	-	-
40	360	300	160	210	120	-	-	-	-
50	720	660	610	550	450	350	130	-	-
60	1200	1140	1100	1020	910	800	550	420	180
70	1620	1560	1520	1420	1350	1230	1000	820	580

LENGTH FOR ACCELERATION
(Level Grade)

Table 9-4

Problem: Determine necessary length for acceleration.

Solution: Table 9-4 yields an acceleration length of 1000 ft on the level.
According to Table 9-5, this should be increased by 2.6.

Therefore: L = (1000) (2.6)
L = 2600 ft

A 2600-ft acceleration length should be provided from the PT of the last horizontal curve to the end of where a 12-ft lane is provided.

* * * * * * * * * *

Sight Distance

Decision sight distance should be provided for drivers on the mainline approaching an entrance terminal. They need sufficient distance to see the merging traffic so they can adjust their speed or change lanes to allow the merging traffic to enter the freeway. Likewise, drivers on the entrance ramp need to see a sufficient distance upstream from the entrance to locate gaps in the traffic stream for merging.

Design Speed of Highway (mph)	Ratio of Acceleration Length on Grade to Acceleration Length on Level				
	Design Speed of Ramp Curve (mph)				
	20	*30*	*40*	*50*	*All Speeds*
	3% ≤ G ≤ 4% (Upgrade)				**3% ≤ G ≤ 4% (Downgrade)**
40	1.3	1.3	--	--	0.7
50	1.3	1.4	1.4	--	0.65
60	1.4	1.5	1.5	1.6	0.6
70	1.5	1.6	1.7	1.8	0.6
	G > 4% (Upgrade)				**G > 4% (Downgrade)**
40	1.5	1.5	--	--	0.6
50	1.5	1.7	1.9	--	0.55
60	1.7	1.9	2.2	2.5	0.5
70	2.0	2.2	2.6	3.0	0.5

Notes:

1. No adjustment is needed on grades less than 3%.
2. The "grade" in the table is the average grade measured over the distance for which the acceleration length applies.

GRADE ADJUSTMENTS FOR ACCELERATION

Table 9-5

For application, drivers on the mainline should have decision sight distance available to the gore nose assuming a 0-foot height of object. Drivers on the ramp should have decision sight distance (based on the ramp design speed) available from the gore nose upstream assuming a 3.75-foot height of object. Section 4-1.02 discusses decision sight distance in more detail.

Superelevation

The ramp superelevation should be gradually transitioned to meet the normal cross slope of the mainline. The principles of superelevation for open highways, as discussed in Section 5-2.05, should be applied to the entrance design. The following criteria should be used:

1. ***Rate***. e_{max} = 6.0%. For a given design speed and radius of curve, Table 5-6 will be used to determine the superelevation rate for the last horizontal curve on the ramp before the freeway/ramp junction.

2. ***Transition Length***. The minimum superelevation transition length from "e" to the normal cross slope of the through travel lane will be 100 feet. This distance applies where the mainline is on a tangent or where the mainline is curving in the same direction as the ramp entrance. Where the mainline is curving away from the ramp entrance and is superelevated, a parallel acceleration lane should normally be used.

3. ***Distribution***. Full superelevation should end at the last 50-ft station occurring a minimum distance of 25 feet before the PT of the last horizontal curve on the ramp. The end of the transition will occur at least 100 feet beyond the station where full superelevation ends.

   Where compound curvature is used on the ramp before the freeway/ramp entrance, the design "e" (for the sharper curve) will end at the last 50-ft station occurring a minimum distance of 25 feet before the PCC at the last horizontal curve.

4. ***Axis of Rotation***. The axis of rotation will typically be about the line on the right edge of travelway (i.e., the control edge profile line) of the entrance ramp. The cross slope of the left and right shoulders will be adjusted during the superelevation transition such that the algebraic difference between the travelway slope and high-side shoulder slope will not exceed 8%.

Cross Slope Rollover

The maximum algebraic difference between the slopes of the entrance lane and through lane is 5 percent, when these two lanes are adjacent to each other.

9-4 RAMP DESIGN

9-4.01 Design Speed

Table 9-6 provides the acceptable ranges of ramp design speed as compared to the design speed on the highway mainline. These design speeds apply to the ramp proper and not to the freeway/ramp junction. For exit ramps, the ramp proper begins 100 feet beyond the gore nose; for entrance ramps, the ramp proper ends 100 feet before the gore nose. If the two intersecting mainlines have different design speeds, the higher of the two should control. However, the ramp design speed may vary, the portion of the ramp nearer the lower-speed highway being designed for the lowest speed.

In general, the higher range of design speeds should apply to directional ramps, such as at diamond and full directional interchanges. The low end of the range should apply to loop ramps and to ramps that terminate with stop control at the minor road intersection. The designer should note that loops with design speeds above 30 mph require extremely large areas and greatly increase the travel distance for vehicles.

If a ramp will be terminated at an at-grade intersection with stop or signal control, the design speeds in the table will not apply to the ramp portion near the intersection.

Highway Design Speed (mph)	50	55	60	65	70
Ramp Design Speed (mph)					
High Range	45	50	50	55	60
Low Range	25	25	30	30	35

RAMP DESIGN SPEEDS

Table 9-6

9-4.02 Cross Section

1. ***Width.*** Widths for one-lane ramps are typically 26 feet from pavement edge to pavement edge. This includes a 14-foot travel lane and combined left and right shoulder widths of 12 feet. For pavement striping, this is normally distributed as a 4-foot left shoulder and an 8-foot right shoulder.

Two-lane ramps are typically 38 feet from pavement edge to pavement edge. This includes a 24-foot travelway, a 4-foot left shoulder and an 8-foot right shoulder.

2. ***Cross Slope***. The typical cross slope of the travelway portion of ramps on tangent should be 2.0% in the direction of the right shoulder. Typically, the right and left shoulders will each slope 4.0% away from the travelway.

3. ***Curbs***. Curbs will be considered based on field conditions (e.g., drainage control). Where used, the sloping curb will normally be designated.

4. ***Side Slopes/Ditches***. The following will apply to the roadside cross section of ramps:

   a. 4:1 fill slopes are typical where the height of fill ≤ 15 feet.
   b. 2:1 fill slopes with guardrail are typical where the height of fill > 15 feet.
   c. 4:1 front slopes and 2:1 back slopes are typical for ditches in earth cuts.
   d. 4:1 front slopes and 4:1 back slopes are typical for ditches in rock cuts.

5. ***Clear Zones***. The clear zone for ramps will be determined from Table 10-1 based on its traffic volume, design speed and roadside slope. This value will apply with or without curbs. The clear zone distance will be measured from either edge of the ramp travelway.

6. ***Bridges and Underpasses***. The Bridge Design Division will determine the roadway width which will be carried across bridges. The full width of the ramp should be carried through an underpass, including the clear zone width, if practical.

9-4.03 Horizontal Alignment

Horizontal alignment will be determined by the design speed and type of ramp. The following should be considered:

1. ***Minimum Radius***. Table 9-7 presents the minimum radius for various ramp design speeds. The values in the table assume a superelevation rate of 6.0%. The designer should note that, for V≤ 40 mph, the maximum degree of curve is higher than that for open-highway conditions (Table 5-2). On ramps, it is appropriate to assume the higher side-friction factors which are used for determining horizontal curves on turning roadways (Section 8-3). These result in higher acceptable maximum degrees of curve.

Design Speed (mph)	Maximum Degree Of Curve	Minimum Radius (ft)
25	38° 15′	150
30	25° 00′	230
35	18° 30′	310
40	13° 15′	430
45	10° 30′	540
50	6° 45′	835
55	5° 15′	1065
60	4° 15′	1340

Note: e = 6.0%.

MINIMUM RADII ON RAMPS

Table 9-7

2. ***Compound Curves***. When compound curves are used on the ramp proper, the radius of the flatter circular arc (R_1) desirably will not be more than 50 percent greater than the radius of the sharper circular arc (R_2). In other words, R_1 is less than or equal to 1.5 R_2. It is acceptable for R_1 to be less than or equal to 2.0 R_2.

For compound curves on ramps, the designer should also ensure that the length of successive circular arcs meet the criteria in Table 9-8. See Example 5.

Radius of Sharper Arc (R_2) (ft)	Length of Adjoining Circular Arc (R_1) (ft)*	
	Minimum	***Desirable***
100	40	60
150	50	70
200	60	90
250	80	120
300	100	140
400	120	180
≥500	140	200

* *These criteria for R_1 apply to a curve which precedes the "Radius of Arc (R_2)" ($R_1 \leq 2.0\ R_2$). For a 3-centered curvature arrangement, the criteria also apply to the length of R_2 which precedes R_3 ($R_3 \leq 2.0\ R_2$).*

LENGTHS OF COMPOUND CURVES (Ramp Proper)

Table 9-8

3. ***Stationing***. The stationing on the ramp must be in the same direction as the stationing on the highway mainline.

4. ***Superelevation***. The following applies:

    a. The maximum superelevation rate is 6.0%.

    b. Table 9-9 presents the criteria for superelevation transition length for ramp curves.

    c. For a one-lane ramp, all curves should have full superelevation from the first 50-foot station occurring a minimum distance of 25 feet after the PC to the last 50-foot station occurring a minimum distance of 25 feet before the PT. For a two-lane ramp, all curves should have full superelevation from the first 100-foot station occurring a minimum distance of 50 feet after the PC to the last 100-foot station occurring a minimum distance of 50 feet before the PT.

Ramp Design Speed (mph)	Change in Cross Slope*	Length of Transition (L_T)(ft)	
		One-Lane Ramp (14-ft Travelway)	***Two-Lane Ramp (24-ft Travelway)***
V ≤ 40	4.0%	100 (minimum)	150 (desirable) 100 (minimum)
	6.0%	150 (desirable) 100 (minimum)	250 (desirable) 150 (minimum)
	8.0%	200 (desirable) 150 (minimum)	350 (desirable) 200 (minimum)
V > 40	All	250	400

* *Change in cross slope is the algebraic difference between the normal cross slope of the travelway portion of the ramp on the tangent and the cross slope of the travelway on the fully superelevated section. For example, if the normal cross slope is 2.0% and the ramp curve is superelevated at 4.0%, the change in cross slope is 6.0%.*

SUPERELEVATION TRANSITION LENGTH
(Ramps)

Table 9-9

For compound curvature on the ramp proper, the design "e" (for the sharper curve) should be reached at the first 50-foot station occurring a minimum distance of 25 feet beyond the PCC.

d. Consecutive curves on ramps may provide deflections in opposite directions and, therefore, are considered reverse curves. Desirably, the reverse curves will be designed with a 100-foot tangent section between the PT and PC. At a minimum, where the PT and PC are coincident (i.e., the tangent length is zero), the design will provide a level cross section.

e. The axis of rotation will typically be about a line on the right edge of travelway (i.e., the control edge profile line). This applies to curves in both the left and right directions and applies regardless of the pavement markings on the ramp. The cross slopes of the left and right shoulders will be adjusted during the superelevation transition such that the algebraic difference between the travelway slope and high-side shoulder slope will not exceed 8.0%.

f. The designer should not superelevate curves on ramps such that the design "e" is maintained on the curve for a very short distance. As a general rule, the minimum distance for "e" should be 100-foot.

g. If the ramp will be terminated at an at-grade intersection with stop or signal control, it is not appropriate to fully superelevate curves near the terminal.

5. ***Sight Distance***. Section 5-2.06 describes how to determine the middle ordinate to provide stopping sight distance at horizontal curves.

* * * * * * * * * *

Example 5

Given: A horizontal curve on an exit ramp is a 3-centered curvature arrangement with the following radii:

R_1 = 500 ft
R_2 = 250 ft
R_3 = 500 ft

Problem: Determine the minimum length of the arc R_1 (from PC to PCC) to safely allow the vehicle to decelerate from the design speed of R_1 to the design speed of R_2.

Solution: Table 9-8 indicates that, if $R_2 = 250$ ft, the preceding arc should be at least 80 ft to allow safe deceleration. Therefore, the distance between the PC & PCC should be 80 ft or more. Note that, because R_3 is flatter than R_2, deceleration need not be considered in determining the length of arc from the PCC to PT. Figure 9-6 illustrates a 3-centered curvature arrangement.

* * * * * * * * * *

9-4.04 Vertical Alignment

Recommended values of limiting gradient are provided in Table 9-10, but for any one ramp the selected gradient is dependent upon a number of factors. These factors include the following:

1. The finished profile grade line is the right edge of the ramp travelway (i.e., the control edge).

2. The steepest gradients should be designed for the center part of the ramp. Landing areas or storage platforms at at-grade intersections should be as flat as practical.

3. Downgrades on ramps should follow the same guidelines as upgrades. They may, however, safely exceed these values by 2 percent, with 8 percent considered a recommended maximum.

4. Practical ramp gradients and lengths can be significantly impacted by the angle of intersection between the two highways and the grade on the two mainlines.

Ramp Design Speed (mph)	20	30	40	50
Maximum Grade (% Range)	6-8	5-7	4-6	3-5

Note: If practical, a maximum grade of 5% should be used.

RAMP GRADIENT GUIDELINES

Table 9-10

5. The minimum longitudinal gradient will be as follows:

    a. rural - 0.25% desirable; 0% minimum
    b. urban (uncurbed) - 0.25% desirable; 0% minimum
    c. urban (curbed) - 0.5% desirable; 0.25% minimum

Stopping sight distance based on the ramp design speed will be the minimum design for crest and sag vertical curves on ramps. See Table 9-11 for specific criteria.

9-4.05 Roadside Safety

The criteria in Chapter Ten (e.g., clear zones, barrier warrants) will apply to the roadside safety design of interchange ramps. One special consideration is the warrants for a median barrier between adjacent on/off ramps, which will be determined on a case-by-case basis. This situation typically occurs at full and partial cloverleaf interchanges. At a minimum, raised islands will be used to separate traffic at these locations. Normally, sloping curbs will be used for the raised islands.

Ramp Design Speed (mph)	Stopping Sight Distance (ft)
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570

STOPPING SIGHT DISTANCE ON RAMPS

Table 9-11

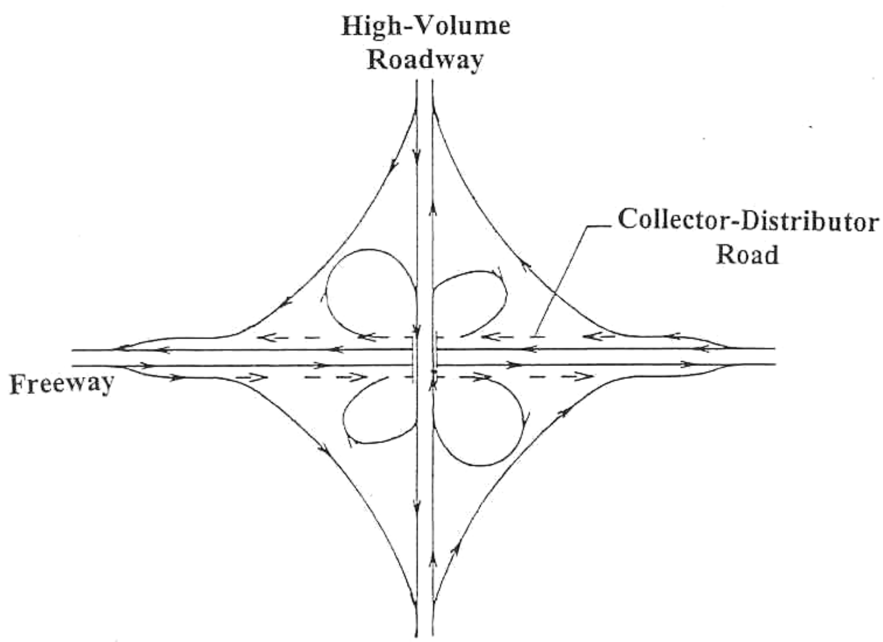
9-5 COLLECTOR - DISTRIBUTOR ROADS

Collector-distributor (C-D) roads are sometimes provided within an interchange to improve its operational characteristics. C-D roads will:

1. remove weaving maneuvers from the mainline, and
2. provide single exits and entrances from the mainline.

C-D roads are most often warranted when traffic volumes are so high that the interchange without them cannot operate at an acceptable level of service, especially in weaving sections. They are particularly advantageous at full cloverleaf interchanges where the weaving between the ramp/mainline traffic can be very difficult. Figure 9-10 illustrates a schematic of a C-D within a full cloverleaf interchange.

C-D roads may be one or two lanes, depending upon the traffic volumes and weaving conditions. The design speed should be the same as the mainline, but not more than 10 mph below the mainline. The separation between the C-D road and mainline should be as wide as practical, but not less than that required to provide the applicable shoulder widths and, if warranted, a longitudinal barrier between the two.



FULL CLOVERLEAF INTERCHANGE
(With Collector-Distributor Road)

Figure 9-10

CHAPTER TEN

ROADSIDE SAFETY

Volume I

- Highway Design Guide –

National Standards

<u>December 2004</u>

Chapter Ten

TABLE OF CONTENTS

Page

TABLE OF CONTENTS
(Continued)

Chapter Ten

ROADSIDE SAFETY

10-1 ROADSIDE CLEAR ZONES

10-1.01 General Definitions

1. ***Clear Zone***. The distance beyond the edge of travel lane that should be clear of any non-traversable hazards or fixed objects.

2. ***Travel Lane***. The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

3. ***Non-Traversable Hazard.*** A general term to describe roadside features which cannot be safely traversed by a run-off-the-road vehicle.

4. ***Parallel Slope***. Cut or fill slope for which the toe runs approximately parallel to the flow of traffic.

5. ***Transverse Slope.*** Cut or fill slope for which the toe runs approximately perpendicular to the flow of traffic. Transverse slopes are typically formed by intersections between the mainline and driveways, median crossovers, or side roads.

6. ***Recoverable Parallel Slope***. Slope which can be safely traversed and upon which an errant motorist has a reasonable opportunity to stop and return to the roadway. Fill slopes 4:1 and flatter are considered recoverable.

7. ***Non-Recoverable Parallel Slope***. Slope which can be safely traversed but upon which an errant motorist is unlikely to recover. The run-off-the-road vehicle will likely continue down the slope and reach its toe. Fill slopes 3:1 and flatter but steeper than 4:1 are considered non-recoverable parallel slopes.

8. ***Critical Parallel Slope***. Slope which cannot be safely traversed by a run-off-the-road vehicle. Depending on the encroachment conditions, a vehicle on a critical slope may overturn. Fill slopes steeper than 3:1 are considered critical.

10-1.02 General Application

The clear zone widths presented in this *Guide* must be placed in proper perspective. The distances imply a degree of accuracy that does not exist. They do, however, provide a good frame of reference for making decisions on providing a safe roadside area. Each application of the clear zone distance must be evaluated individually, and the designer must exercise good judgment. In general, the designer should provide as much clear zone as can be practically obtained.

The following factors must be considered in determining the recommended clear zone:

1. ***Scope of Work/Roadway Classification***. The recommended clear zone distance will be based on the roadway classification (i.e. NHS/Non-NHS) and scope of work (i.e. new construction, reconstruction, rehabilitation, overlay).

2. ***Speed/Traffic Adjustments***. The recommended clear zone distance will be based on the highway design speed and traffic volumes.

3. ***Roadside Cross Section***. The recommended clear zone distance will be based on the type of side-slopes.

4. ***Traffic Distribution (Multi-Lane Highways).*** Table 10-1 presents traffic volume distribution by lane for both 4-lane and 6-lane facilities. Although no specific adjustments are presented for clear zone values, these lane distributions should be considered. For example, all other factors being equal, Table 10-1 indicates that the clear zone on the right side of a 4-lane divided facility should be more than that on the median side.

When using recommended clear zone distances, the designer should consider the following:

1. ***Context.*** If an obstacle lies just beyond the clear zone, it may be appropriate to remove or shield the obstacle if costs are reasonable. Conversely, the clear zone should not be achieved at all costs. Limited right-of-way or unacceptable construction costs may lead to installation of a barrier or a design exception allowing no protection at all.

2. ***Boundaries.*** The designer should not use the clear zone distances as boundaries for introducing roadside hazards such as bridge piers, non-breakaway sign supports, utility poles or landscaping features. These should be placed as far from the roadway as practical.

Clear zones should be free of all non-traversable hazards and fixed objects. These include, but are not limited to, the following:

1. bridge piers and abutments,

2. boulders,
3. culvert headwalls,
4. retaining walls,
5. non-breakaway sign and luminaire supports,
6. trees,
7. utility poles,
8. permanent bodies of water, and
9. embankments

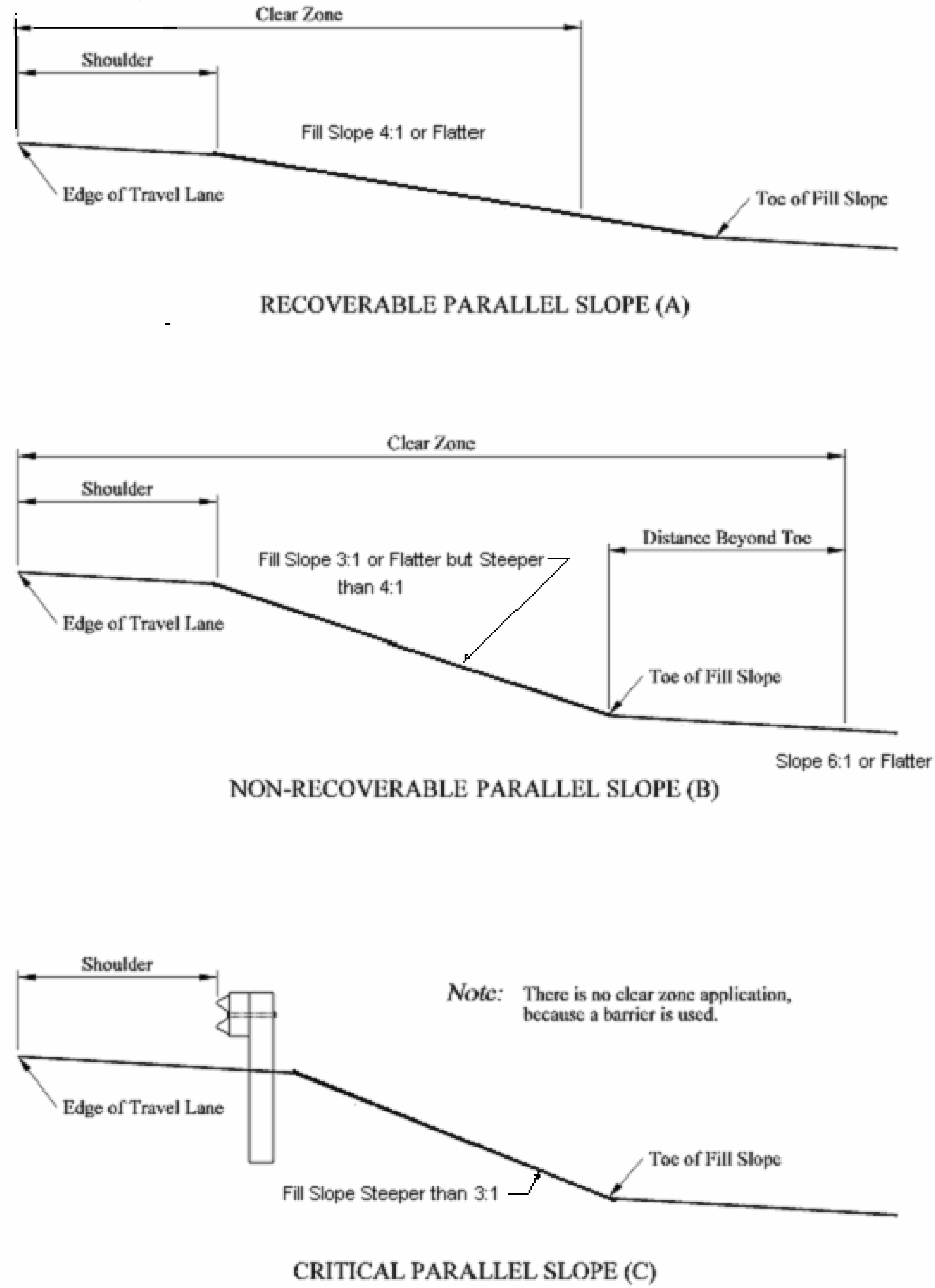
For roadside features within the clear zone, a determination that the feature is a hazard will be made on a case-by-case, project-by-project basis.

4-Lane Roadway		
AADT	***Median Lane (%)***	***Right Lane (%)***
12,000	20	80
24,000	25	75
36,000	33	67
48,000	41	59
60,000	50	50

6-Lane Roadway			
AADT	***Median Lane (%)***	***Center Lane (%)***	***Right Lane (%)***
24,000	22	47	31
48,000	31	43	26
72,000	35	40	25
96,000	37	38	25
120,000	37	37	26

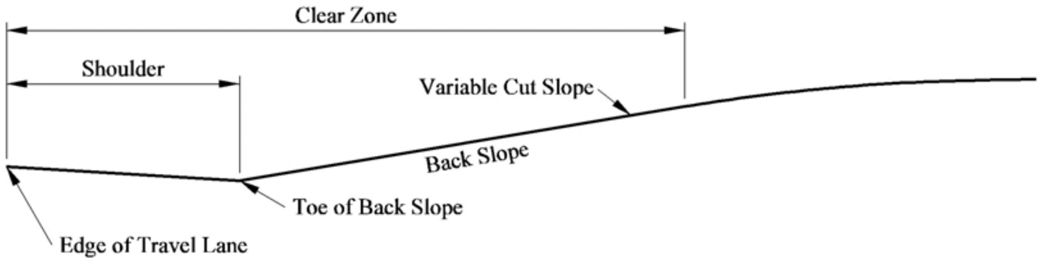
LANE DISTRIBUTION OF TRAFFIC VOLUMES
(Multi-Lane Highways)

Table 10-1

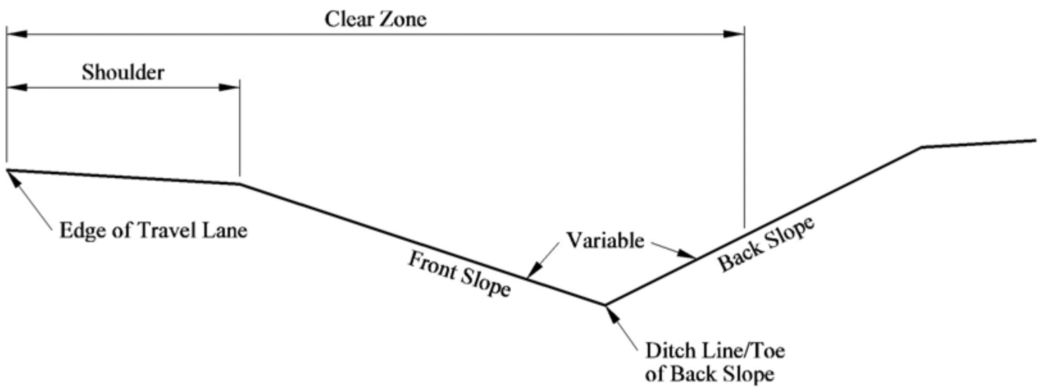


ROADSIDE CROSS SECTION SCHEMATICS
(Clear Zone Application)

Figure 10-1



CUT SLOPE (Without Ditch) (D)



CUT SLOPE (With Ditch) (E)

ROADSIDE CROSS SECTION SCHEMATICS
(Clear Zone Application)
(Continued)

Figure 10-1

10-1.03 Parallel Slopes

Roadside clear zones will vary depending on the type of parallel slope.

Recoverable Fill Slopes. For parallel slopes 4:1 and flatter (Figure 10-1(A)), the recommended clear zone distance can be determined directly from Table 10-2. This table applies to new construction or reconstruction projects on the NHS. The recommended clear zone for other projects can be determined directly from other appropriate tables in this Guide.

Non-Recoverable Fill Slopes. For parallel slopes steeper than 4:1 but 3:1 or flatter (Figure 10-1(B)), the recommended clear zone includes a clear distance beyond the toe of the slope, according to the following procedure:

a. The slope beyond the toe of the non-recoverable fill slope will probably be 6:1 or flatter. Determine the clear zone distance for a 6:1 or flatter slope from Table 10-2.

b. Subtract the shoulder width from this clear zone distance.

c. The remaining distance will be the required distance beyond the toe of the slope. The minimum distance will be 10 feet.

If this clear zone cannot be achieved, barrier shall be required.

This procedure applies to new construction or reconstruction projects on the NHS. Clear zone for other projects can be determined using this procedure in conjunction with other appropriate tables in other chapters this Guide. Barrier should be considered but will not be required on other project types if clear zone conditions cannot be met at the toe of slope.

Critical Fill Slopes. For parallel slopes steeper than 3:1 (Figure 10-1(C)), barrier will be required on all project types.

Cut Slopes (Without Ditch). For parallel cut slopes that don't have a ditch (Figure 10-1(D)), determine the clear zone distance for 6:1 or flatter slope from Table 10-2 for all project types. Slope requirements related to stability and safety shall be considered.

The following examples illustrate how to determine the clear zone for various parallel slopes.

* * * * * * * * * *

NEW CONSTRUCTION/RECONSTRUCTION PROJECTS
(NHS and Major Arterials)

Design Speed (mph)	Design AADT **	Fill Slopes			Cut Section With Ditch Figure10-1(E)
		Recoverable (Figure 10-1(A))		Non-recoverable Figure10-1(B)	
		6:1 or Flatter	5:1 to 4:1		
40 or Less	Under 750	7 - 10	7 - 10	SEE PROCEDURE IN SECTION 10-1.03	SEE PROCEDURE IN SECTION 10-1.04
	750 - 1500	10 - 12	12 - 14		
	1500 - 6000	12 - 14	14 - 16		
	Over 6000	14 - 16	16 - 18		
45 - 50	Under 750	10 - 12	12 - 14		
	750 - 1500	14 - 16	16 - 20		
	1500 - 6000	16 - 18	20 - 26		
	Over 6000	20 - 22	24 - 28		
55	Under 750	12 - 14	14 - 18		
	750 - 1500	16 - 18	20 - 24		
	1500 - 6000	20 - 22	24 - 30		
	Over 6000	22 - 24	26 - 32*		
60	Under 750	16 - 18	20 - 24		
	750 - 1500	20 - 24	26 - 32*		
	1500 - 6000	26 - 30	32 - 40*		
	Over 6000	30 - 32*	36 - 44*		
65 - 70	Under 750	18 - 20	20 - 26		
	750 - 1500	24 - 26	28 - 36*		
	1500 - 6000	28 - 32*	34 - 42*		
	Over 6000	30 - 34*	38 - 46*		

* *On non-freeways, the clear zone distance may be limited to 30 feet for practicality and to provide a consistent roadway template.*

** *Use the AADT projected for the design year for the overall project.*

RECOMMENDED CLEAR ZONE DISTANCES
(In Feet Measured From Edge of Travel Lane)

Table 10-2

Example 1 (Recoverable Fill Slope)

Given: Project Scope of Work – Reconstruction, NHS
Fill Slope – 4:1
Design Speed – 60 mph
Design AADT – 7000

Problem: Determine the recommended clear zone distance.

Solution: From Table 10-2, the clear zone distance should be 36 feet - 44 feet. Note that this distance will apply regardless of the shoulder width. However, as indicated in a footnote to the table, the clear zone distance may be limited to 30 feet based on specific site conditions to provide a more practical design.

Example 2 (Non-Recoverable Fill Slope)

Given: Project Scope of Work – Reconstruction, NHS
Fill Slope – 3:1
Design Speed – 60 mph
Design AADT – 2000
Shoulder Width – 6 ft

Problem: Determine the recommended clear zone distance.

Solution: If the slope can be flattened to a 4:1 slope practically and economically, the clear zone distance can be taken directly from Table 10-2 as in Example 1. If this is not possible, a clear distance must be provided at the toe of the slope. From Table 10-2 the clear zone distance should be 26 feet – 30 feet for a 6:1 slope. After subtracting the 6 foot shoulder, a minimum 20 foot clear area is required at the toe of the slope. If this clear zone cannot be achieved, a barrier shall be required.

* * * * * * * * * *

10-1.04 Cut Slopes (With Ditches)

Ditch sections, as illustrated in Figure 10-1(E), are frequently constructed in roadside cuts. The applicable clear zone across a ditch section will depend upon the front slope, the back slope, the horizontal location of the toe of the back slope, and various highway factors. The designer will use the following procedure to determine the recommended clear zone distance.

The following procedure applies specifically to new construction or reconstruction projects on the NHS. Clear zone for other projects can be determined using procedures and discussions in the other chapters of the Guide according to the project types.

1. ***Check Front Slope***. Slopes steeper than 3:1 will require guardrail. Slopes steeper than

4:1 but flatter than 3:1 will require a clear distance beyond the toe of front slope as described for non-recoverable fill slopes, except that the back slope may be as steep as 2:1. For slopes 4:1 or flatter determine the clear zone based on the ditch front slope as described for recoverable fill slopes. Back slopes within the clear zone should be 4:1 or flatter, but may be as steep as 2:1.

2. ***Check Location of Ditch Line.*** If the front slope is 4:1 or flatter, determine if the toe of the back slope is within the clear zone. If the toe is at or beyond the clear zone, then the designer usually need only consider roadside hazards within the clear zone on the front slope. If the toe is within the clear zone, the designer should evaluate the practicality of relocating the toe of back slope. This may be accomplished by, for example, providing a flat bottom ditch or by deepening the ditch line. If the toe of back slope will remain within the clear zone, or if the front slope is steeper than 4:1, #3 below will apply.

3. ***Check Back Slope.*** If the toe of the back slope is within the clear zone distance from #1 above, a clear zone should be provided on the back slope. This clear zone will be determined as follows:

   a. Back Slope 3:1 or Steeper ($V > 50$ mph). The clear zone will be 10 feet beyond the toe or the distance determined in Step #1 beyond the edge of travel lane, whichever is less.

   b. Back Slope 3:1 or Steeper ($V \leq 50$ mph). The clear zone will be 5 feet beyond the toe or the distance determined in Step #1 beyond the edge of travel lane, whichever is less.

   c. Back Slope Flatter than 3:1. The clear zone will be the distance determined in Step #1 beyond the edge of travel lane.

* * * * * * * * * *

Example 3 (Clear Zones) (cut slope with ditch)

Given: Front Slope – 4:1
Ditch Bottom Width – 0 ft (V-ditch)
Back Slope – 2:1
Design Speed – 60 mph
Design AADT – 4000

Problem: Determine the recommended clear zone distance.

Solution: Using the procedure in Section 10-1.04, the following applies:

1. ***Check Front Slope.*** According to Table 10-2, the clear zone distance for the front slope is 32 feet – 40 feet, with a practical limit of 30 feet acceptable.

2. ***Check Location of Ditch Line.*** Desirably, the toe of the back slope will be at or beyond 30 feet. If this is not practical, #3 below will apply.

3. ***Check Back Slope.*** For a 2:1 back slope and a design speed of 60 mph, the clear zone distance will be to 10 feet beyond the toe of back slope or to 30 feet from the edge of travel lane, whichever is less.

* * * * * * * * * *

10-1.05 Horizontal Curves

On the outside of horizontal curves, run-off-the-road vehicles may travel a greater distance from the travel lane before regaining control of the vehicle. The designer may choose to modify the clear zone distance obtained from Table 10-2 for horizontal curvature. These modifications are normally only considered where crash history indicates a need, or a specific site investigation shows a definitive crash potential which could be significantly lessened by increasing the clear zone width and such increases are cost effective.

Where adjustments will be applied, Table 10-3 provides recommended factors for clear zones on horizontal curves. A diagram illustrates the application on a curve.

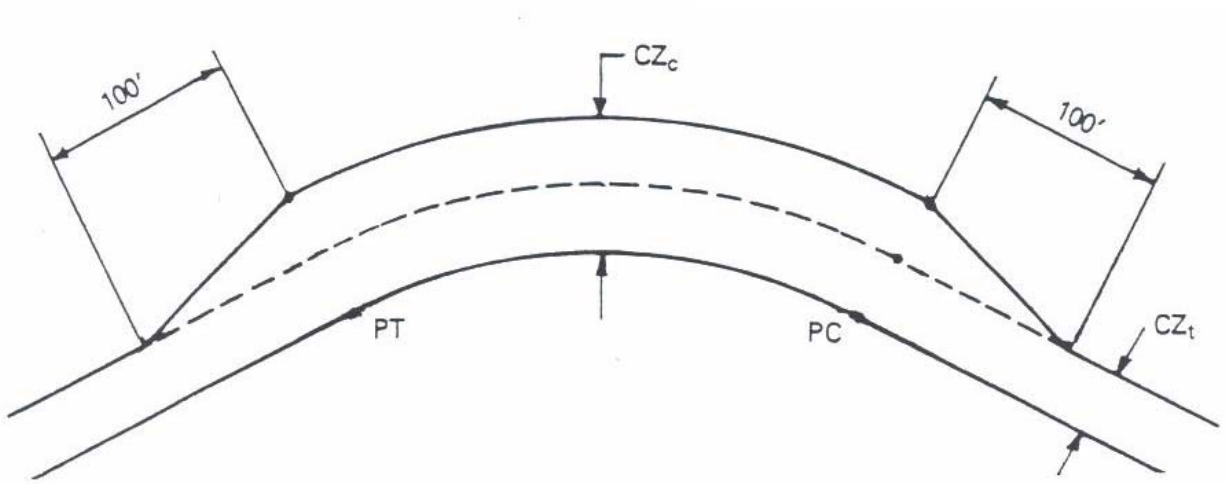
10-1.06 Curbed Sections

Most curbs do not have a significant re-directional capability and therefore a minimum clear zone commensurate with prevailing traffic volumes and design speeds should be provided where practical. Curb should not be a justification for reducing clear zone. In urban areas with posted speed limits of 35 mph or less, aboveground utility poles may be installed 5 feet behind the face of curb. In locations where insufficient right-of-way or other restrictions are present and no other practical solution exists, aboveground utility poles may be installed 1 foot behind the face of curb. A minimum 3 foot clear zone should be provided at intersections and driveways.

Degree of Curve	K_{CZ}, Curve Correction Factor						
	Design Speed (mph)						
	40	*45*	*50*	*55*	*60*	*65*	*70*
2.0	1.08	1.10	1.12	1.15	1.19	1.22	1.27
2.5	1.10	1.12	1.15	1.19	1.23	1.28	1.33
3.0	1.11	1.15	1.18	1.23	1.28	1.33	1.40
3.5	1.13	1.17	1.22	1.26	1.32	1.39	1.46
4.0	1.15	1.19	1.25	1.30	1.37	1.44	
4.5	1.17	1.22	1.28	1.34	1.41	1.49	
5.0	1.19	1.24	1.31	1.37	1.46		
6.0	1.23	1.29	1.36	1.45	1.54		
7.0	1.26	1.34	1.42	1.52			
8.0	1.30	1.38	1.48				
9.0	1.34	1.43	1.53				
10.0	1.37	1.47					
15.0	1.54						

$CZ_C = (CK_T)(K_{CZ})$

Where: CZ_C = clear zone distance on outside of curve, ft
CZ_T = clear zone distance on tangent section, ft
K_{CZ} = curve correction factor, ft



HORIZONTAL CURVE ADJUSTMENTS

Table 10-3

10-2 ROADSIDE BARRIER WARRANTS

10-2.01 Embankments

A roadside barrier shall be considered where an embankment is steeper than 4:1 on NHS and other major arterials and will be warranted if a clear area cannot be provided at the toe of the slope. On all roads, a roadside barrier will be warranted where an embankment is steeper than 3:1.

10-2.02 Roadside Hazards

The recommended clear zone distances for various highway conditions, should be free of any fixed objects and non-traversable hazards. The need for a barrier will be based on the relative severity between impacting a barrier and impacting the hazard. Based on the discussion in Section 10-1.02, the designer must use judgment to determine whether or not a roadside feature is a roadside hazard. The decision for barrier protection will be based on site-specific factors, including traffic volumes, design speed, alignment, proximity of hazard to travel lane, and crash history.

Once the designer has concluded that a barrier is warranted, the first attempt should be to eliminate the need for the barrier. This may be accomplished by removing or relocating the hazard or by making the hazard breakaway. If these are not practical, a barrier should be installed only if engineering judgment indicates it is practical. For example, it would probably not be practical to install a barrier to shield an isolated point obstacle, such as a tree, located near the edge of the clear zone.

10-2.03 Bridge Rails/Parapets

Barrier protection is normally warranted on all approach ends to bridge rails or parapets, and it is warranted on the trailing ends on two-way roadways. No roadside barrier is needed on the trailing end on a one-way roadway, unless a barrier is warranted for other reasons (e.g., steep slopes).

All designs for barrier/bridge rail connections should be coordinated with the Urban and Federal Bridge Program.

10-3 ROADSIDE BARRIER TYPES

Table 10-4 presents the most common types of roadside barriers that are approved for use in Maine. The table summarizes the hardware requirements for each system and references the *MDOT Standard Details* for more information. The next two sections briefly describe each system and its typical usage.

10-3.01 "W" Beam

The "W" beam system with strong posts is a semi-rigid system. This system consists of a steel “W” beam or rail, an offset block, and wood or steel posts. A major objective with a heavy post system is to prevent a vehicle from "snagging" on the posts. This is achieved by using blocks to offset the posts from the longitudinal beam and by establishing 6’-3”as the maximum allowable post spacing.

The Department has approved the use of two guardrail "W" beam systems. One uses 6” x 8” timber posts, and the other uses W6x8.5 or W6x9 steel posts. On non-freeways, the two systems are usually presented on a competitive bid basis in the contract proposal. On freeways, the steel post system is designated.

10-3.02 Thrie Beam

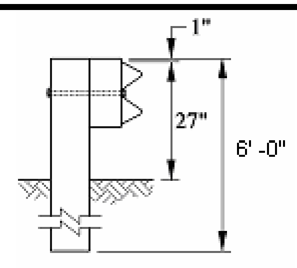
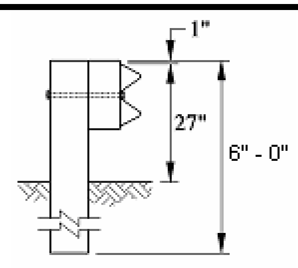
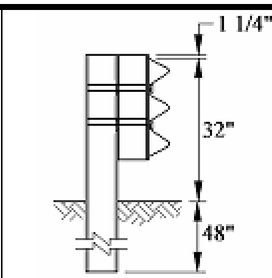
The thrie beam guardrail is also a semi-rigid system with strong posts. The depth of the beam and the offset bracket is approximately 1½ times as great as those for the "W" beam. The thrie beam is primarily used when there is inadequate deflection distance (e.g., less than 3 feet) for the "W" beam.

10-3.03 Other Types

Several other types of guardrail are approved for use in specific situations. Steel backed timber guardrail may be used in areas where aesthetic requirements exist, such as on scenic highways or in historic districts. Corrosion resistant steel guardrail (rusty rail), a variation of the “W” Beam, may be used in similar situations. There are several cable guardrail systems that meet current standards which may be considered. These can only be used when large deflection distances can be accommodated, and when exposure to significant snowplow contact is not expected. Cable guardrail may be considered when visibility through the guardrail is necessary or desired.

10-3.04 Guardrail and Guardrail Terminal Selection

Guardrail and guardrail terminal selection shall be based on the highway system as recommended in the Guardrail and Guardrail Terminal Policy. Refer to the current policy for details.

			
System	"W" Beam Guardrail (Wood Posts)	"W" Beam Guardrail (Steel Posts)	Thrie Beam Guardrail (Steel Posts)
AASHTO Designation	SGR04b	SGR04b	SGR09c
MDOT Standard Detail	606(03)	606(03)	606 (25)
Post Spacing	6'-3"	6'-3"	6'-3"
Deflection Distance *	3'-0"	3'-0"	2'-0"
Post Type	6x8 Treated Wood Post	W6x9 Steel Post	W6x9 Steel Post
Beam Type	Steel "W" Section 12 ga.	Steel "W" Section 12 ga.	Steel Thrie Beam 12 ga.
Offset Blocks	6x8x14 Treated Wood Block Or Composite Plastic Block	6x8x14 Treated Wood Block Or Composite Plastic Block	6x8x21½ Treated Wood Block Or Composite Plastic Block

* Clear distance from the back of the post to the roadside object.

ROADSIDE BARRIERS

Table 10-4

10-4 ROADSIDE BARRIER LAYOUT

10-4.01 Length of Need

Length of need is generally defined as the distance from the point where the hazard ends to the third post in from the end of the guardrail terminal. The length of need determination criteria in Section 10-4 apply to guardrail applications in all scopes of work on NHS and Non-NHS projects.

The designer must determine the beginning and ending of the barrier length of need to properly shield the roadside obstacle or embankment. The following discussion will apply.

General Approach/Application

The Department has adopted two methodologies to determine the length of need for roadside barriers:

1. ***Method No. 1***. On NHS projects use a 10° and on Non-NHS projects use a 15° angle off the back of the hazard to locate the beginning of the barrier need.

2. ***Method No. 2.*** Use the methodology presented in the AASHTO *Roadside Design Guide* to locate the beginning of the barrier need.

Method No. 2 may yield, depending on site conditions, considerably longer lengths of barrier than Method No. 1. At some sites, these longer lengths are not considered cost effective, and Method No. 1 is judged to be a more reasonable application. The following summarizes the Department's application of the two Methods for determining the length of need for specific sites:

1. ***Embankments.*** Use Method No. 1.

2. ***Roadside Obstacles.*** Use Method No. 2. Check to see if one of the following conditions exist at the site:

   a. Because of the nature of the terrain, it may be improbable or impossible for a run-off-the-road vehicle to traverse behind the barrier and reach the roadside obstacle.

   b. Because of the location of the barrier, it may be that a run-off-the-road vehicle would have to exceed the clear zone distance to reach the roadside obstacle.

   If either of the conditions exist at the site, it is acceptable to use Method No. 1 to determine the barrier length of need. In addition, based on a site-by-site evaluation, it is acceptable to use Method No. 1 to shield roadside obstacles if, in the judgment of the designer, it is not cost-effective to install the additional length of barrier required by Method No. 2.

3. ***Bridge Parapet/Rails.*** The length of barrier in advance of bridge parapets/rails will be 100 feet or the length-of-need calculation based on Method No. 2, whichever is greater. For the

trailing end on two-way roadways, it will be 50 feet or the length-of-need calculation based on Method No. 2, whichever is greater. Based on a site-by-site evaluation, it is acceptable to use Method No. 1 to shield a bridge parapet/rail if, in the judgment of the designer, it is not cost effective to install the additional length of barrier required by Method No. 2. The 100-ft minimum (approach end) or 50-ft minimum (trailing end) will govern if greater than the length of barrier from Method No. 1.

The following sections present the design details for Methods No. 1 and No. 2.

Method No. 1

Method No. 1 determines the barrier length of need based on an angle off the back of hazard. On NHS projects use a 10° and on Non-NHS projects use a 15° angle. The following figures illustrate the application of Method No. 1:

1. Figure 10-2 presents the methodology as it applies to embankments.
2. Figure 10-3 presents an example for the application to embankments.
3. Figure 10-4 presents the methodology as it applies to roadside obstacles.
4. Figure 10-5 presents an example for the application to roadside obstacles.

$$L = \frac{L_H - L_B}{\tan 10^\circ} \quad \text{or} \quad L = \frac{L_H - L_B}{\tan 15^\circ} \qquad \text{(Equation 10-2)}$$

L = length of need.

L_H = distance from edge of travel lane to back of obstacle. May be equal to the clear zone.

L_B = distance from edge of travel lane to face of guardrail. The barrier offset should be considered as discussed in Section 10-4.02.

Other variables to consider:

L_C = recommended clear zone.

L_F = distance from edge of travel lane to front of obstacle, based on deflection distance from Table 10-4 and barrier offset.

Method 1 Steps

1. **Determine Clear Zone (L_C).**
Obstacles: Clear zone determination will be based on the roadway classification, etc., as discussed in Section 10-1.

   Embankments: The clear zone will be to the toe of the embankment.

2. **Determine Barrier Offset (L_B).** Determine offset based on proposed shoulder width. Lateral placement will be discussed in Section 10-4.02

3. **Determine Lateral Offset. (L_H).**
Obstacles: Determine the offset to back of obstacle and compare to clear zone. The lesser distance may become L_H, but use of the more conservative greater distance should be given careful consideration.

   Embankments: Equal to the clear zone distance.

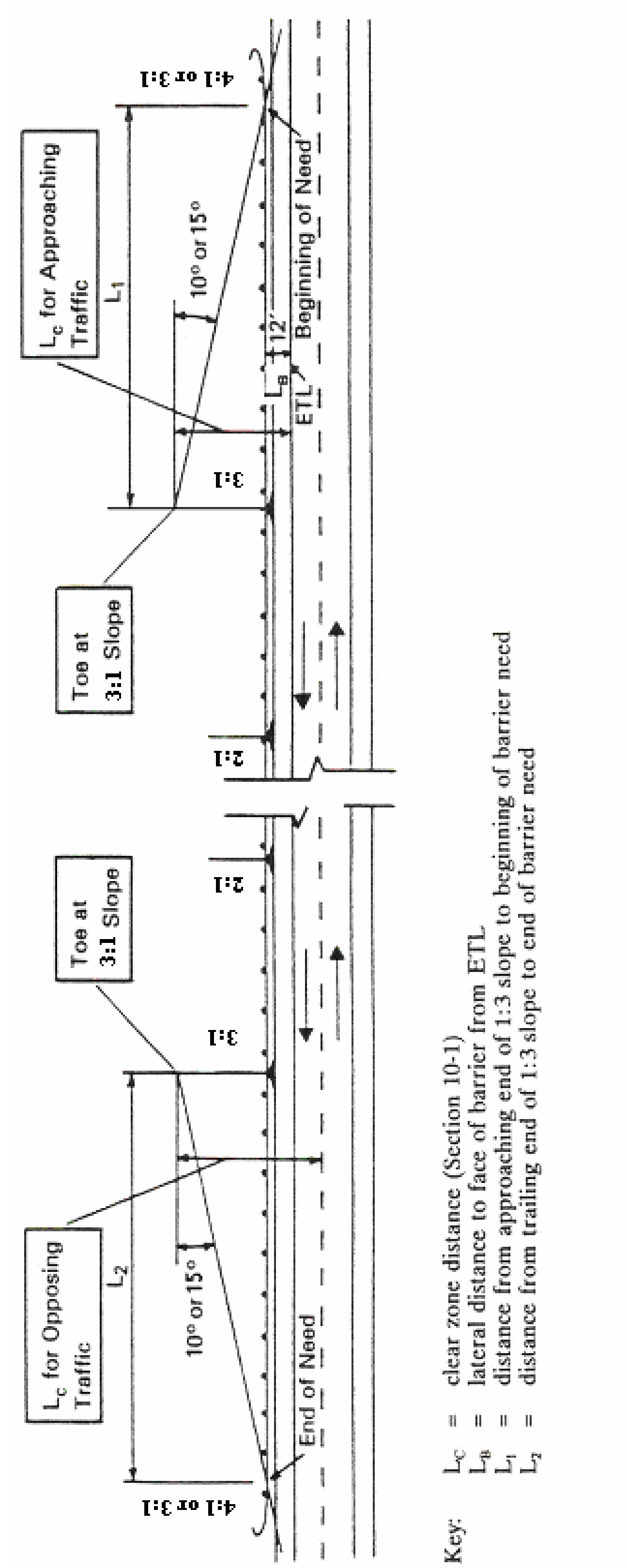
4. **Apply Angles.** Measure 10° or 15°, as appropriate, from the lateral offset. See the following Figures. The intersection of this line and the run of barrier will locate the end of the length of need. The following step gives an equation for this distance.

5. **Determine Length of Need (L) .** Use the following equation:
$\mathrm{L} = \dfrac{L_H - L_B}{\tan 10°}$ $\mathrm{L} = \dfrac{L_H - L_B}{\tan 15°}$ tan 10° = 0.176327 tan 15° = 0.267807

6. **End Treatment**. A crashworthy terminal should be used at the end of the guardrail run. Most terminals have full redirectional capabilities beyond the third post. In general, the first 12.5 feet of the terminal can be outside the length of need. The third post would be placed at the length of need. This should be verified by checking the manufacturer's reccomendations. For a one-way roadway, an unanchored end is acceptable at the trailing end. The end will be located a minimum of 50 feet beyond an obstacle and 66 feet beyond a steep embankment.

7. **Opposing Traffic.** For opposing traffic on a two-way roadway, a length of need calculation for the trailing end is necessary if the break in the embankment slope or any part of the obstacle is within the clear zone as measured from the centerline of the roadway. See Step 8. The trailing end of the barrier will be 50 feet beyond the end of the roadway hazard, including end treatments.

8. **Opposing Traffic Length of Need.** Where needed, the length of need calculation for opposing traffic is determined using the same procedure as for approaching traffic, except that all distances will be measured from the centerline of the roadway. The minimum distance to the end of the barrier, excluding end treatment, will be 50 feet beyond the end of an obstacle and 66 feet beyond the end of a steep embankment.



BARRIER LENGTH OF NEED (Method 1)
(Embankments)

Figure 10-2

BARRIER LENGTH OF NEED (Method 1)
(Embankments)

Figure 10-2

Example:

Given: Project Scope – Reconstruction
Roadway – Two-way traffic, 12-foot lanes, 10-foot typical shoulders
Design Speed – 60 mph
AADT – 7000
Roadside – 4:1 fill slope leading to 2:1 slope. At the point where the slope is 3:1, the height of embankment is 10 feet. The distance from the ETL to the break in the fill slope is 15 feet.

L_B = 12 feet from the ETL

Problem: Determine beginning and ending of barrier run.

Solution: Following the step-by-step procedure on Figure10-2 (Method No. 1):

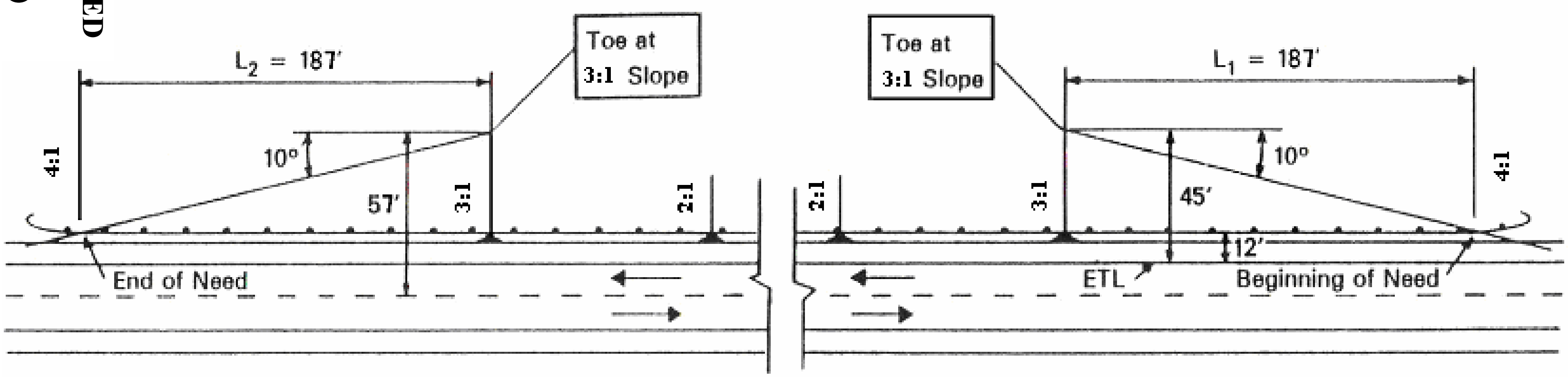
1. Table 10-2 applies to a reconstruction project. Based on the highway conditions (4:1 slope), the clear zone range is 36-44 feet, with a practical limit of 30 feet from the edge of travel lane. Because the 3:1 slope begins within the clear zone, a clear distance should be provided to the toe of the 3:1 slope. Based on an embankment height of 10 feet, the lateral distance to the toe of the 3:1 slope is 15' (to the slope break) + 30' (3:1 slope for 10') = 45'
2. The 10° angle is plotted on the example figure below.
3. The distance L_1 is:

   $$L_1 = \frac{(45 - 12)}{.176327} = 187 \text{ feet}$$

4. For the opposing traffic, the break in the embankment slope is 27 feet from the roadway centerline (15' + 12'). From Table 10-2, the clear zone is 30-32 feet (flat slope across the roadway). Therefore, the embankment is within the clear zone for opposing traffic. The total clear zone for opposing traffic is measured from the roadway centerline to the toe of the 3:1 slope. Therefore, L_C = 12' + 15' + 30' = 57'
5. The offset to the barrier is 24 feet (12' + 12'). The distance L_2 is:

   $$L_2 = \frac{(57 - 24)}{.176327} = 187 \text{ feet}$$

6. Not applicable.



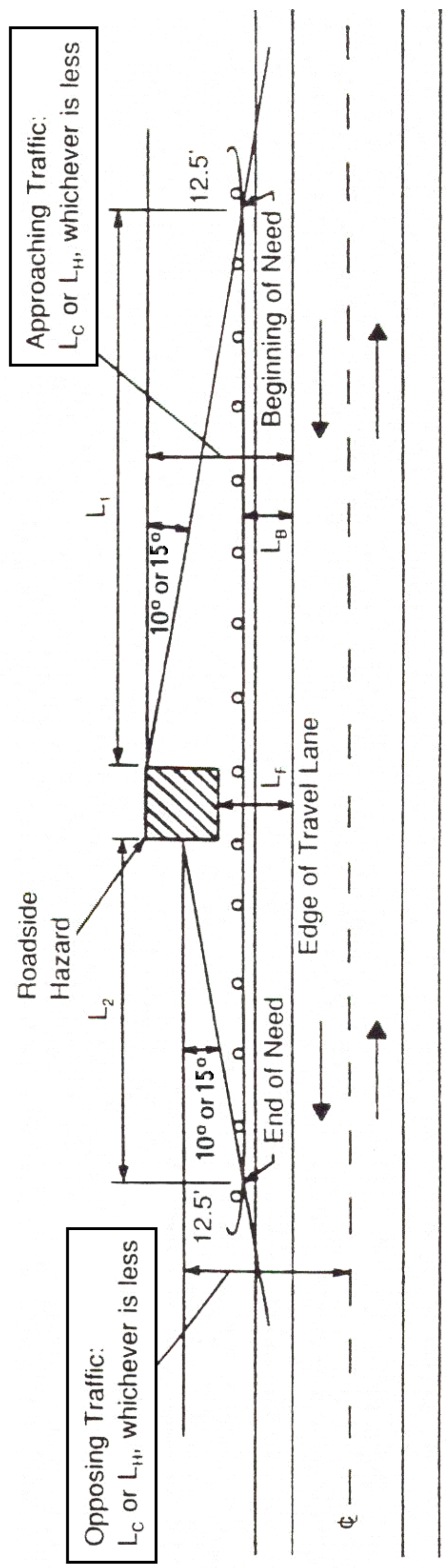
BARRIER LENGTH OF NEED (Method 1)
(Example - Embankments)

Figure 10-3

BARRIER LENGTH OF NEED
(Method 1)
(Example - Embankments)

Figure 10-3

Note: Use L_C or L_H , whichever is less. If a portion of the roadside obstacle falls Outside the clear zone (i.e. $L_H > L_C$), the designer should consider Determining the barrier length of need based on the greater L_H distance.



Key:
- L_C = clear zone distance (Section 10-1)
- L_F = lateral distance to front of roadside obstacle from ETL
- L_H = lateral distance to back of roadside obstacle from ETL
- L_B = lateral distance to face of barrier from ETL
- L_1 = distance from approaching end of roadside obstacle to beginning of barrier need
- L_2 = distance from trailing end of roadside obstacle to end of barrier need

BARRIER LENGTH OF NEED (Method 1)
(Roadside Obstacles)

Figure 10-4

BARRIER LENGTH OF NEED (Method 1)
(Roadside Obstacles)

Figure 10-4

Example:

Given: Project Scope – Reconstruction
Roadway – Two-way traffic, 12-foot lanes, 10-foot typical shoulders
Design Speed – 60 mph
AADT – 4000
Roadside – 4:1 fill slope

L_F = 15 feet from the ETL
L_H = 25 feet from the ETL
L_B = 12 feet from the ETL

Problem: Determine beginning and ending of barrier run.

Solution: Following the step-by-step procedure on Figure10-4 (Method No. 1):

1. Table 10-2 applies to a reconstruction project. Based on the highway conditions the clear zone range is 32-40 feet, with a practical limit of 30 feet from the edge of the travel lane.

2. For traffic approaching the obstacle, the back of the obstacle is within the clear zone (25 feet from ETL). Therefore, the 25-foot distance will apply.

3. The 10° angle is plotted on the example figure below.

4. The distance L_1 is:

$$L_1 = \frac{(25 - 12)}{.176327} = 74 \text{ feet}$$

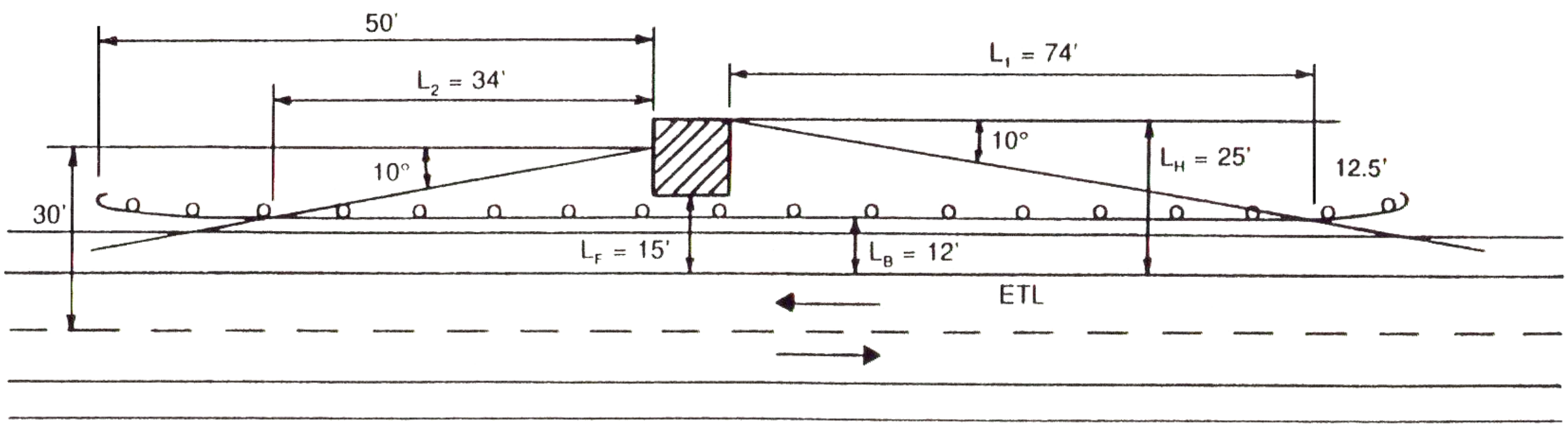
5. For the opposing traffic, the front of the obstacle is 27 feet from the roadway centerline (15’ + 12’). Therefore, the obstacle is within the clear zone of 30 feet.

6. The back of the obstacle is 37 feet from the centerline. Therefore, at a minimum, the 30-foot clear zone distance will apply in determining the end of barrier need. The offset to the barrier is 24 feet (12’ + 12’). The distance L_2 is:

$$L_2 = \frac{(30 - 24)}{.176327} = 34 \text{ feet}$$

The end of the barrier would be 34’ + the portion of the guardrail terminal end that is gateable. In most cases this is 12.5’ , so 34’ + 12.5’ = 46.5’

7. Not applicable.



BARRIER LENGTH OF NEED (Method 1)
(Example - Roadside Obstacles)

Figure 10-5

BARRIER LENGTH OF NEED (Method 1)
(Example - Roadside Obstacles)

Figure 10-5

Method No. 2

Figure 10-6 illustrates the variables that must be considered in designing a roadside barrier to shield an obstacle using Method No. 2, which comes from the AASHTO *Roadside Design Guide*. This method applies to both flared and tangential approaches to guardrail end terminals as shown in Figure 10-6. Only tangential guardrail approaches should be used. Once the appropriate variables have been selected, the required length of need can be calculated from the following formulas:

Unflared Design:

$$X = \frac{L_R\,(L_H - L_2)}{L_H} \qquad \text{(Equation 10-3)}$$

where:

$$Y = L_2 \qquad \text{(Equation 10-4)}$$

X, Y = coordinates of end of barrier need.

L_R = runout length (see Table 10-5).

L_H = distance from edge of travel lane to back of obstacle. The AASHTO *(Roadside Design Guide)* refers to this distance as Lateral Extent.

L_2 = distance from edge of travel lane to face of guardrail.

Other variables to consider:

L_C = recommended clear zone.

L_S = shy line offset, or distance at which barrier is no longer perceived as an obstacle by a driver (see Table 10-5).

L_3 = distance from edge of travel lane to front of obstacle. Equals L_2 + minimum deflection distance from Table 10-4.

Method 2 Steps

1. **Determine Clear Zone.** Find the clear zone based on Table 10-2. Compare with L_H , the distance to back of obstacle. Use the smaller distance as L_H in determining length of need.

2. **Determine Barrier Offset (L_2).** Find L_S , the shy line offset from Table 10-6. As discussed in Section 10-4.02, L_2 should be at the shy line or the shoulder width, whichever is greater. Desirably, the shoulder will be widened by 2 feet and the barrier face will be placed at the edge of the widened shoulder.

3. **Determine Offset to Obstacle (L_3).** Find the deflection distance from Table 10-4 for the guardrail. The distance to the front of the obstacle, L_3, can be no less than the barrier offset, L_2 , plus the deflection distance.

4. **Determine Runout Length (L_R).** Use Table 10-5.

5. **Determine Length of Need Coordinates (X,Y).** Use Equations 10-3 and 10-4.

Example 4

Given: The following site conditions apply to a roadside obstacle (see Figure 10-7):

ADT = 7000
V = 60 mph
Slope = 6:1 fill slope
Shoulder Width = 8 ft
L_H = 25 ft (to back of obstacle)

Problem: Determine the details of barrier location. Use the W-beam system with an unflared layout. $L_1 = 0$.

Solution: The following steps apply:

1. ***Determine Clear Zone.*** From Table 10-2, the clear zone is 30 ft. Therefore, L_C = 30 ft. The obstacle is within the clear zone and, therefore, L_H = 25 ft.

2. ***Determine Barrier Offset (L_2).*** From Table 10-5, L_S = 8.0' (the shy line offset). This equals the shoulder width. With the desirable 2' extra widening, for this example, use L_2 = 10'.

3. ***Determine Offset to Obstacle (L_3).*** From Table 10-4, the deflection distance for the W-beam guardrail is 3'. $L_3 = L_2 + 3' = 13'$. Therefore, the front of the obstacle can be no closer than 13' from the edge of travel lane.

4. ***Determine Runout Length (L_R).*** From Table 10-5, L_R = 425'.

5. ***Determine Length of Need Coordinates (X,Y).*** For the approaching traffic, Equations 10-3 and 10-4 yield the following:

$$X = \frac{425\ (25\ -10)}{25} = 255\text{ft}$$

$$Y = 10\text{ ft}$$

For the opposing traffic and assuming 12' travel lanes, the following adjustments are made:

$$L_C = 30\ ft$$

$$L_H = 37\ ft$$

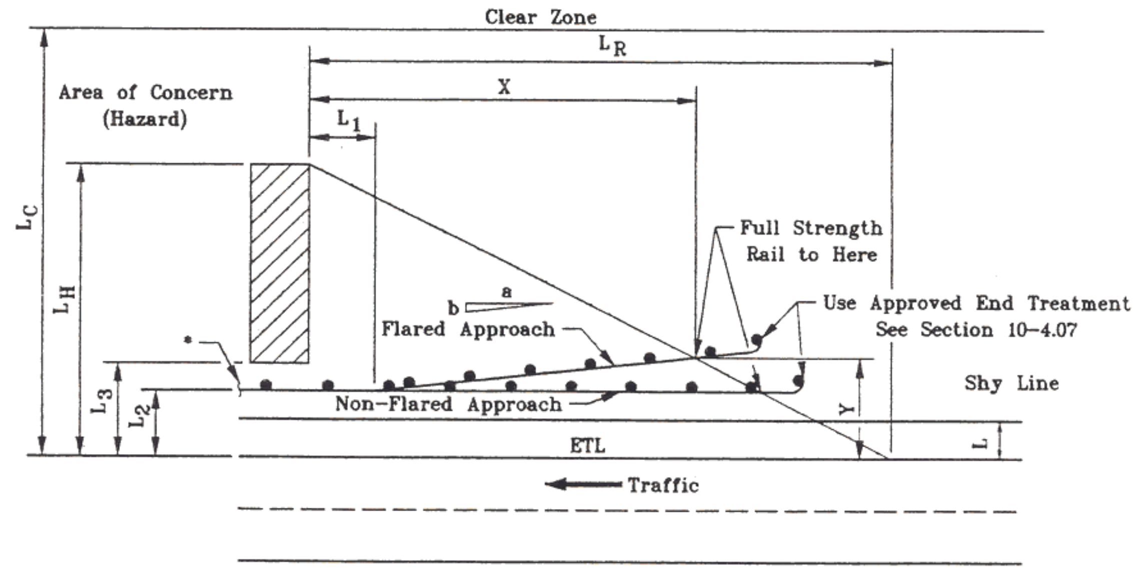
Since the back of the obstacle is outside of the clear zone for opposing traffic, *L_H may be set equal to L_C = 30'.* However, for illustration, the X,Y coordinates for the trailing end are calculated assuming L_H = 37' (i.e., to the back of the obstacle):

$$L_2 = 10\ ft + 12\ ft = 22\ ft$$

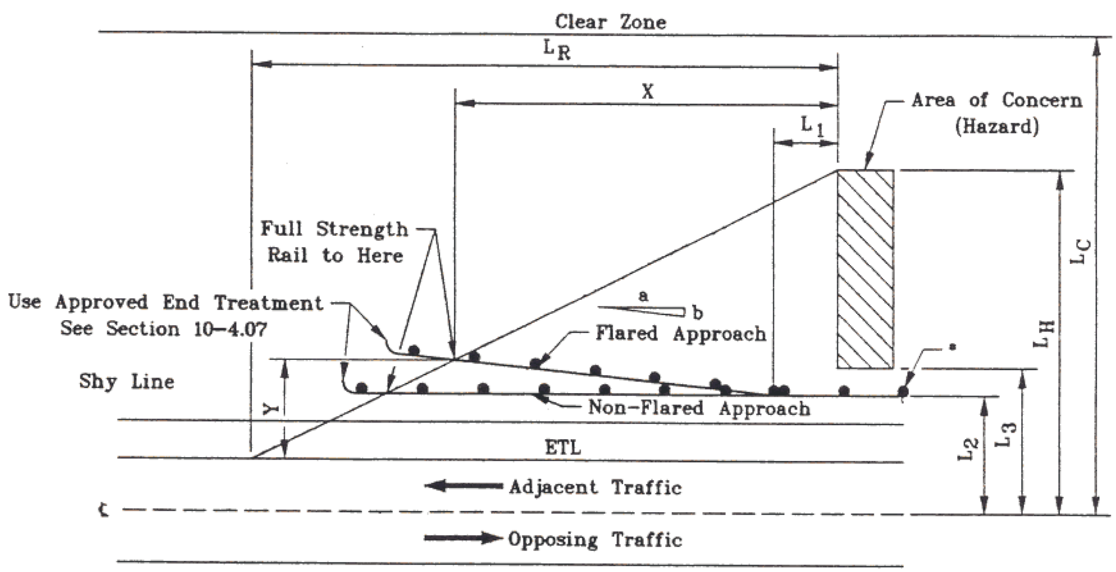
$$L_R = 425\ ft$$

$$X = \frac{425(37 - 22)}{37} = 172'$$

$$Y = 22'$$



APPROACH TREATMENT FOR ONCOMING TRAFFIC (a)



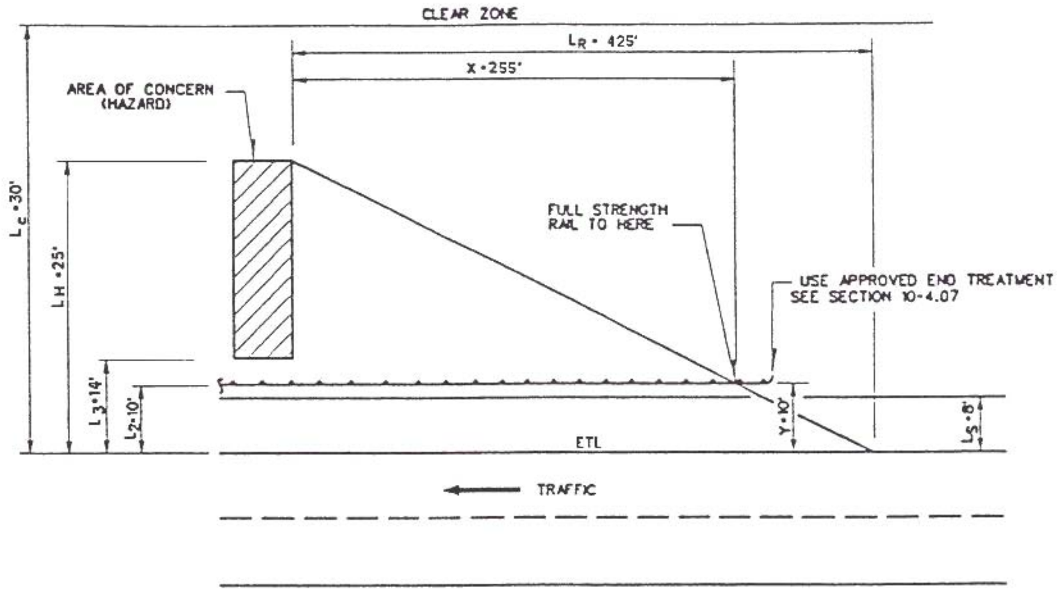
APPROACH TREATMENT FOR OPPOSING TRAFFIC (b)

* The distance beyond the hazard should be 50’ or as determined by a length-of-need calculation for opposing traffic

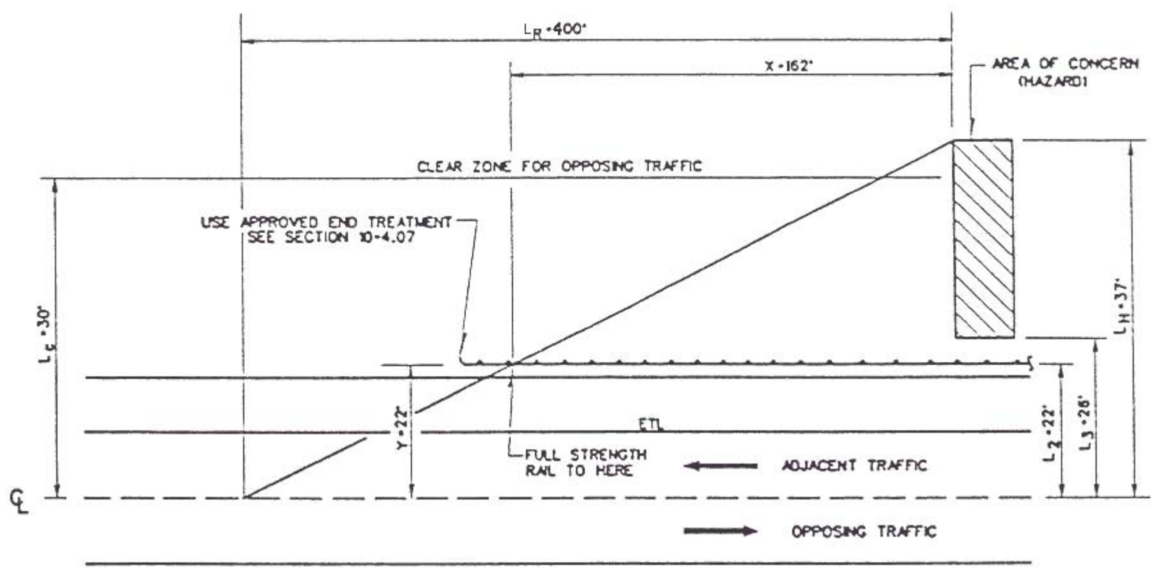
Note: X and Y are shown for the flared approach

BARRIER LENGTH OF NEED FOR ROADSIDE OBSTACLE (Method 2)

Figure 10-6



APPROACH TREATMENT FOR ONCOMING TRAFFIC (a)



APPROACH TREATMENT FOR OPPOSING TRAFFIC (b)

BARRIER LENGTH OF NEED FOR ROADSIDE OBSTACLE (Method 2)
(Example 4)

Figure 10-7

Design Speed (mph)	**Design Traffic Volume (ADT)**				**L_S Shy Line Offset (ft)**	**Flare Rates**		
	Over 6000	***2000-6000***	***800-2000***	***Under 800***		**Inside of Shy Line**	***Outside of Shy Line***	
	L_R (ft)	**L_R (ft)**	**L_R (ft)**	**L_R (ft)**			**Guardrail**	**CMB***
70	475	445	395	360	10.0	30:1	15:1	20:1
65	450	425	370	345	9.0	28:1	14:1	19:1
60	425	400	345	330	8.0	26:1	14:1	18:1
55	360	345	315	280	7.25	24:1	12:1	16:1
50	330	300	260	245	6.5	21:1	11:1	14:1
45	260	245	215	200	5.75	18:1	10:1	12:1
40	230	200	180	165	5.0	16:1	8:1	10:1
35	200	185	165	150	4.25	15:1	8:1	9:1
30	165	165	150	130	3.5	13:1	7:1	8:1
25	140	130	120	110	2.75	12:1	7:1	8:1
20	110	100	90	80	2.0	10:1	7:1	8:1

* Concrete Median Barrier

DESIGN ELEMENTS FOR BARRIER LENGTH OF NEED

Table 10-5

10-4.02 Lateral Placement

The following will apply to the lateral placement of a roadside barrier:

1. ***Relative to Shoulder.*** Typical barrier location relative to the shoulder shall be two feet beyond the normal shoulder edge. In restricted locations, it is acceptable to place the barrier at the normal shoulder edge, but only if the following conditions can be met. Guardrail should not be placed closer than 4 feet from the edge of travel lane or 17 feet from the

centerline. The greater distance will control. The 17 feet minimum is critical to accommodate snowplow widths without excessive encroachment on the opposing lane.

2. ***Deflection Distance.*** The dynamic deflection of the barrier, as presented in Table 10-4, cannot be violated. Double-nesting the rails or decreasing the post spacing to 3' 1.5" will decrease the deflection distance by 50%. Either method must extend at least 25 feet in advance of and beyond the trailing end of the obstacle being shielded.

3. ***Relative to Embankments.*** A minimum of 3 feet should be provided between the face of the barrier and the break in a fill embankment. When minimal impacts are an issue, a 2 foot space may be used, but longer guardrail posts are required.

4. ***Bridge Approaches.*** Short runs of barrier at less than the desirable lateral offset are acceptable at bridges where the bridge width is narrower than the normal face-of-barrier-to-face-of-barrier width.

5. ***Shy Line Offset.*** It is desirable that a barrier be placed at or beyond the shy line offset, which is the distance beyond which a barrier will not be perceived as a hazard. See Table 10-5 for shy line offset criteria.

10-4.03 Barrier Gaps

Barrier gaps of less than 200 feet should be connected, unless the gap is needed for access (e.g., driveways, maintenance operations).

10-4.04 Placement on Slopes

Roadside barriers should not be placed on roadside slopes steeper than 10:1. This also applies to the area approaching the beginning of the barrier installation.

10-4.05 Placement Behind Curbs

If practical, roadside barriers should not be placed in conjunction with sloping or vertical curbs. Where this is necessary, the following will apply:

1. ***Barrier/Curb Orientation.*** The face of the barrier should be flush with the face of the curb (i.e., at the gutter line). The height of the barrier is measured from the pavement surface. Curb height shall not exceed 4 inches.

2. ***Sidewalks.*** A barrier may be warranted where a curb and sidewalk are provided. If the sidewalk is adjacent to the curb, it will likely not be practical to place the barrier flush with the curb. Table 10-6 presents the criteria for placement of a barrier beyond the curb. If a barrier will be placed closer to the curb than these distances, a thrie beam or rub rail should be used.

3. ***Sidewalks and Bridge Rails.*** A barrier may be warranted approaching a bridge rail and a sidewalk may be provided across the bridge. When guardrail is offset from the face of curb, the height of the barrier is measured from the ground beneath the rail. It may not be practical to meet the criteria in Table 10-6. The desirable treatment in these cases will be determined on a case-by-case basis.

4. ***Guardrail Terminal/Curb Orientation.*** Guardrail terminals should not be placed behind curb. Where there is no alternative, curb height should be reduced to 2 inches approximately 50 feet in advance of the terminal. For flared terminals, the 2 inch height should be carried an additional 37 feet beyond the upstream end. For tangent terminals, the 2 inch height should be carried 12 feet beyond the upstream end and the terminal should be offset 1 foot to keep the impact head behind the face of curb.

10-4.06 Rub Rails

The placement of a barrier in combination with a side slope or curb may create the possibility that the bumper on an impacting vehicle will contact the barrier below the longitudinal member (e.g., the "W" beam). This may cause the vehicle to snag the posts supporting the longitudinal member. In these cases, a rub rail should be considered where a potential snagging problem may exist.

10-4.07 Guardrail Terminals

The following will apply to the barrier end treatment:

1. ***Approach End.*** If the approach end is within the clear zone, an approved terminal will be required. Where there is physically not space available for an approved flared terminal, the designer may consider using a tangential terminal on the approach ends of roadside barriers. In addition, a designer may consider other end treatments described in the AASHTO *Roadside Design Guide* (e.g., buried-in-back slope) in special situations. Guardrail should not be terminated with an unanchored radius. If an approved terminal is not feasible, consideration should be given to use of a curved guardrail system with breakaway posts and an anchorage assembly. See the MDOT Standard Details for more information.

2. ***Trailing End.*** On the trailing end of barrier runs on a one-way roadway, an unanchored terminal may be used. An approved terminal should always be used on the trailing end of a barrier on a two-way roadway.

3. ***End Treatment Selection.*** Guardrail terminal selection shall be based on the highway system designation. Refer to the current Guardrail and Guardrail Terminal Policy for details.

Design Speed (mph)	**Recommended Distance Behind Face of Curb7 for Placement of Barrier**	
	Desirable	***Acceptable***
< 45	Barrier will be flush with face of curb at gutter line.	$\geq$ 6 ft.
$\geq$45		> 11 ft

Notes: 1. These criteria apply to both sloping and vertical curbs.

2. Where barrier will be placed closer to curb than recommended distance, a thrie beam or rub rail should be used.

BARRIER PLACEMENT BEHIND CURBS

Table 10-6

10-5 ROADSIDE DRAINAGE FEATURES

The primary purpose of roadside drainage is to properly convey water away from or below the roadway (e.g., storm runoff, rivers, streams). Chapter Twelve discusses drainage design in detail. However, the designer must also consider the safety aspects of roadside drainage features. The following presents the Department's criteria:

1. ***Roadside Ditches***. As discussed in Section 10-1.04, the designer should locate the toe of the back slope outside of the clear zone, if practical. However, if this is not practical, a barrier will not normally be warranted to shield the roadside ditch, unless other roadside hazards are within the clear zone.

2. ***Curbs.*** See Section 10-4.05 for criteria on the use of curb and barrier in combination.

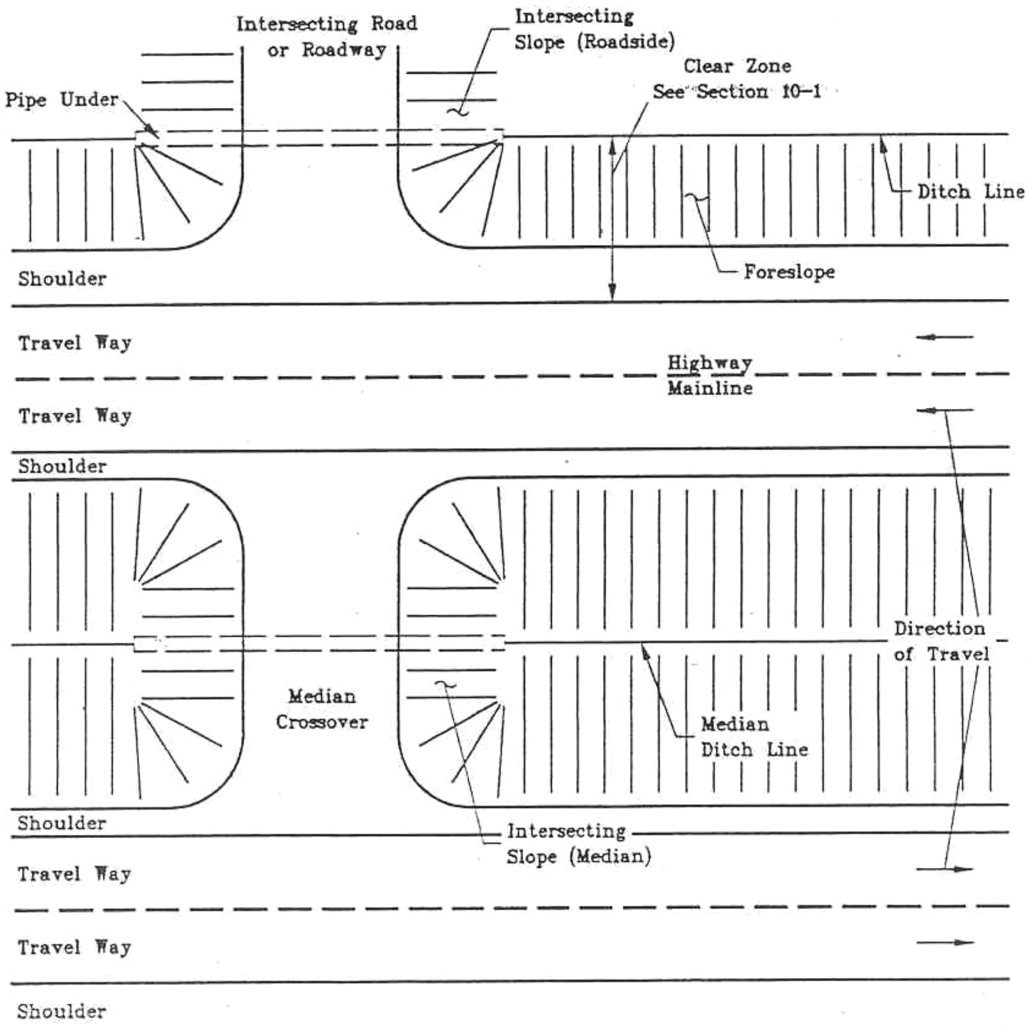
3. ***Cross Drainage Structures (Culverts).*** These convey water beneath the roadway. Ideally, the culvert end sections will be outside of the roadside clear zone as determined from Section 10-1. However, this may be impractical because it may require a major discontinuity in the shape of the fill slope. The MDOT Standard Details present the Department's typical design for culvert end sections based on the type of culvert, culvert size and fill slope. These end sections are typically used for all culverts whether they are within or outside of the clear zone.

4. ***Intersecting Slopes/Drainage Structures.*** A highway mainline may intersect a driveway, side road or median crossing. This will present a slope that may be impacted at a 90-degree angle by run-off-the-road vehicles from the mainline. See Figure 10-8. The following criteria will apply:

    a. Medians -- Intersecting slopes in the median should be 10:1.

    b. Roadside -- For all roads and driveways that intersect the mainline, the desirable intersecting slope is 6:1 within the clear zone. It is acceptable for the intersecting slope to be as steep as the side slope along the main road, but not to exceed 3:1. Where a barrier is shielding the slope, intersecting slopes steeper than 3:1 are acceptable.

5. ***Catch Basins.*** These should be flush with the roadway or ground surface.



INTERSECTING SLOPES

Figure 10-8

10-6 MEDIAN BARRIERS

10-6.01 Warrants

The following summarizes the Department's criteria:

1. ***Freeways.*** Figure 10-9 presents the warrants for a median barrier based on median width and traffic volumes. Note that the traffic volumes are based on a five-year projection. In the areas shown as optional, the decision to use a median barrier will be based on construction and maintenance costs and crossover accident experience. A median barrier may also be warranted on medians not within the optional or warranted area, if a significant number of crossover accidents have occurred.

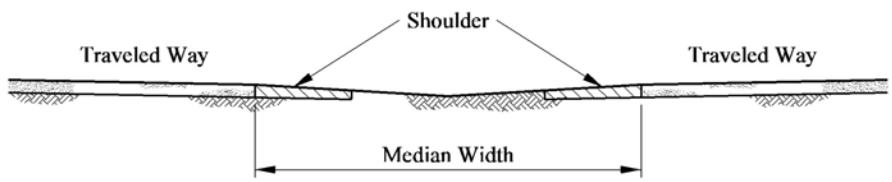
2. ***Non-Freeways.*** On other highways, some judgment must be used to determine median barrier warrants. On highways without full access control, the median barrier must terminate at each at-grade intersection, which is undesirable. In addition, lower speeds will reduce the likelihood of a crossover accident. Therefore, on non-freeway highways, the designer should evaluate the crash history, traffic volumes and speeds, median width, alignment, sight distance and construction costs to determine the need for a median barrier. Figure 10-9 can be used for some guidance.

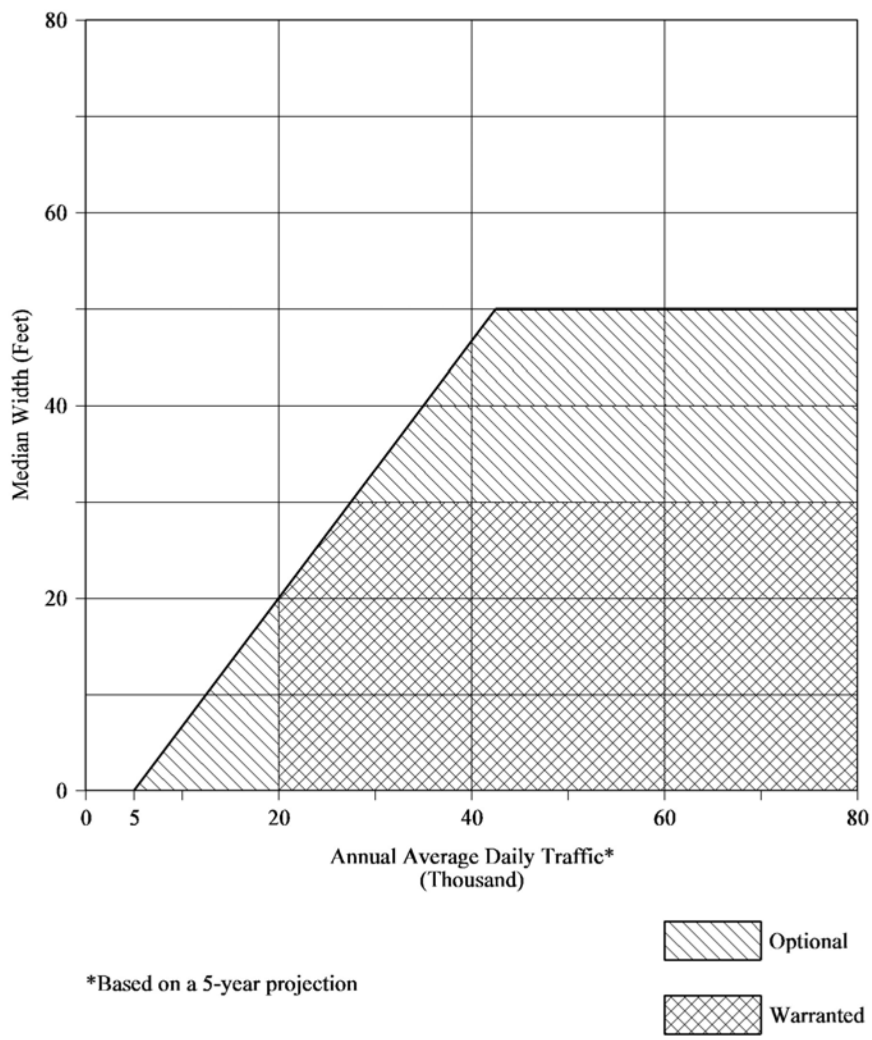
10-6.02 Types

Table 10-7 presents the types of median barriers that are approved for use in Maine. The following briefly describes each type:

1. ***"W" Beam.*** The "W" beam median barrier with strong posts is a semi-rigid system. Its performance is similar to the "W" beam guardrail system. This median barrier is most applicable to medians with intermediate width. A special application of the W-beam median barrier is for the separation of adjacent on/off ramps at interchanges.

   The Department has approved the use of two "W" beam median barriers. One uses 6x8 timber posts, and the other uses W6x8.5 or W6x9 steel posts. On non-freeways, the two systems are usually presented on a competitive bid basis in the contract proposal. On freeways, the steel post system is designated.

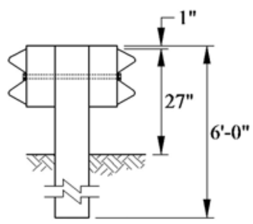


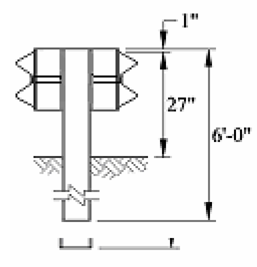


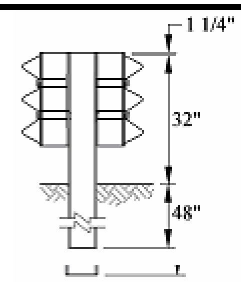
*Based on a 5-year projection

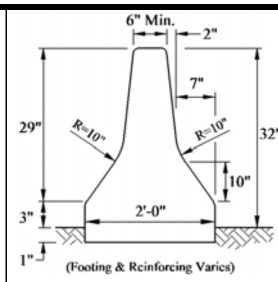
MEDIAN BARRIER WARRANTS

Figure 10-9









System	"W" Beam Median Barrier (Wood Posts)	"W" Beam Median Barrier (Steel Posts)	Thrie Beam Median Barrier (Steel Posts)	Concrete Median Barrier
AASHTO Designation	SGM04b	SGM04b	SGM09c	SGM11a
Post Spacing	6'-3"	6'-3"	6'-3"	N/A
Deflection Distance *	3'-0"	3'-0"	2'-0"	0
Post Type	6x8 Treated Wood Post	W6x9 Steel Post	W6x9 Steel Post	N/A
Beam Type	Steel "W" Section 12 ga.	Steel "W" Section 12 ga.	Steel Thrie Beam 12 ga.	N/A
Offset Brackets	6x8x14 Treated Block	6x8x14 Treated Wood Block Or Composite Plastic Block	6x8x21½ Treated Wood Block Or Composite Plastic Block	N/A

* Clear distance from the face of the rail to the roadside object.

MEDIAN BARRIERS

Table 10-7

2. ***Thrie Beam***. The thrie beam median barrier on strong posts is also a semi-rigid system. It performs similar to the thrie beam guardrail system. As with the thrie beam guardrail, the thrie beam median barrier is primarily used where there is inadequate deflection distance (e.g., less than 3 feet) for the "W" beam median barrier

3. ***Concrete Median Barrier.*** The concrete median barrier (CMB) is a rigid system that does not deflect upon impact. A variation is a half-section of the CMB system. These may be necessary where the median barrier must divide to go around a fixed object in the median (e.g., bridge piers).

10-6.03 Median Barrier Selection

The Department has not adopted specific criteria for the selection of median barrier systems. This involves a objective evaluation of the many trade-offs between systems. The designer should evaluate each of the following factors when selecting a median barrier:

1. ***Median Width.*** The median width will significantly affect the probability of impact (i.e., the number of hits) and the likely angles of impact. The former will influence maintenance costs; the latter influences safety. The greater the offset to the barrier, the higher the likely angle of impact. Specifically for the CMB, offsets of more than 15 feet should be avoided. Therefore, considering both maintenance and safety, this favors the use of the CMB on median widths up to about 30 feet and either the "W" beam or thrie beam system for wider medians.

2. ***Traffic Volumes.*** The higher the traffic volume, the greater the likelihood of impacts on the median barrier. From a maintenance perspective, this favors the CMB; from a safety perspective, this favors the metal beam systems.

3. ***Heavy Vehicle Traffic.*** The CMB is more likely to restrain and redirect heavy vehicles (trucks and buses) than the metal beam systems. Therefore, where there is a high volume of heavy vehicles, this may favor the CMB even on medians wider than 30 feet. Considering the two metal beam systems, the thrie beam performs somewhat better when impacted by heavy vehicles.

4. ***Costs.*** The initial cost of the CMB will exceed, perhaps by a wide margin, the initial cost of the two metal beam median barriers. The CMB may also require a closed drainage system in the median, further increasing initial costs. However, the maintenance costs per impact on the CMB will probably be far less, which favors the CMB in narrow medians and/or on high-volume highways.

5. ***Maintenance Operations.*** Two factors are important. First, maintenance response time will influence safety. The longer that a damaged section of median barrier is present, the greater the likelihood of a second impact on a substandard barrier. This observation favors the use of the CMB which normally sustains far less damage when impacted. Second, the

maintenance operations for repairing damaged barrier can interrupt traffic operations. It is particularly undesirable to close a traffic lane to repair a barrier. The consideration of maintenance operations generally favors the use of the CMB in narrow medians and/or on high-volume highways.

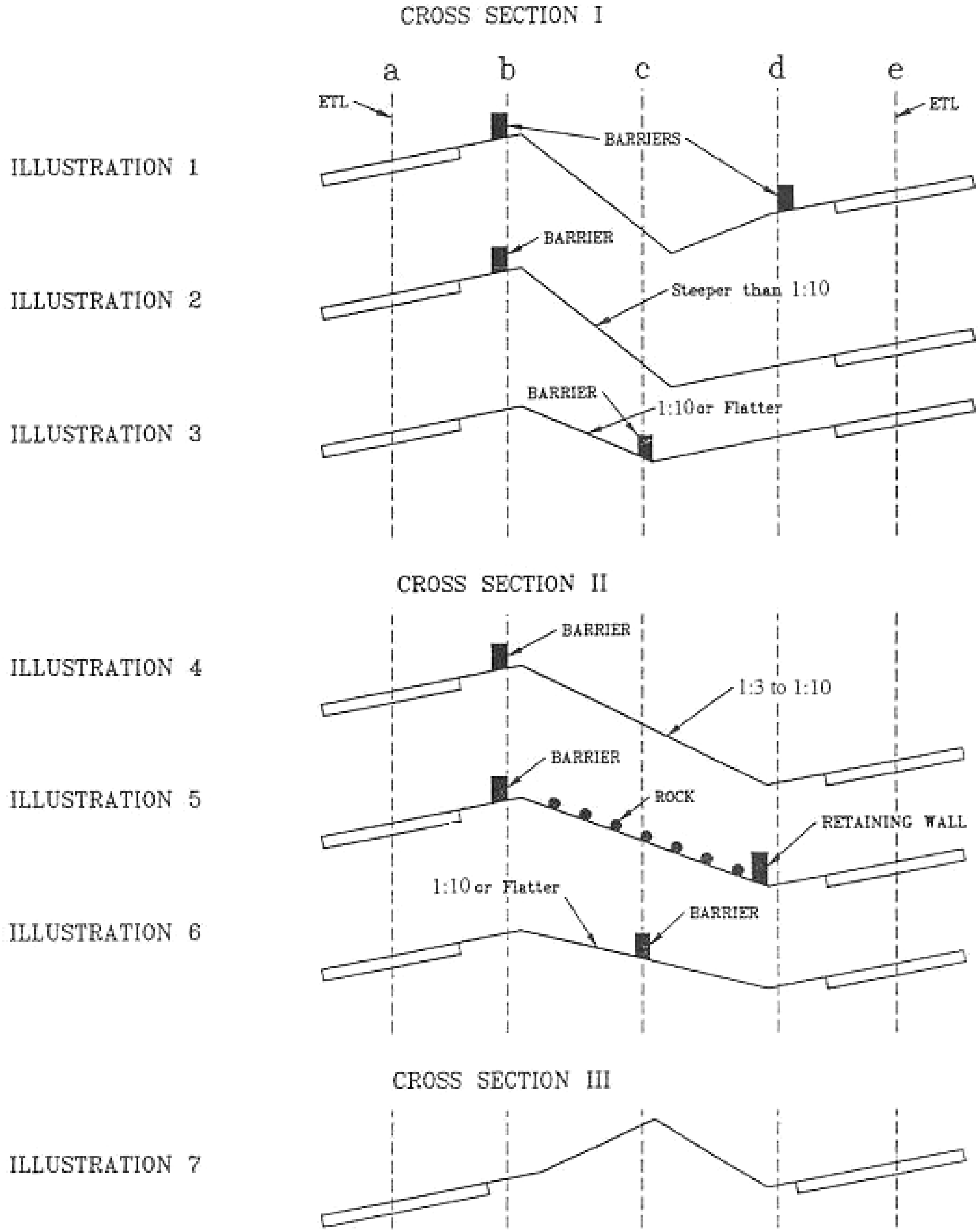
10-6.04 Median Barrier Layout

The information presented in Section 10-4 on roadside barrier layout also applies to median barriers (e.g., placement behind curbs). The following presents criteria specifically for the design of median barriers:

Sloped Medians

A median barrier should not be placed on a slope steeper than 10:1. Where the median slopes are steeper than 10:1, the designer should give special consideration to median barrier placement. Figure 10-10 illustrates three basic types of sloped medians. The following discusses barrier placement for each type (assuming a median barrier is warranted):

1. For Cross Section I, the designer should determine if the individual slopes warrant protection based on the criteria in Section 10-2. If both slopes warrant protection (Illustration 1), a roadside barrier should be placed at "b" and "d". If only one slope warrants protection, the median barrier should be placed to shield that slope. If "W" beam is used, a rub rail should be placed on the median side of the median barrier for potential impacts on that side. If neither slope warrants protection and both slopes are steeper than 10:1 (Illustration 2), median barrier should be placed at "b" or "d", whichever is shielding the steeper slope. Again, a rub rail should be used with the "W" beam median barrier. If the slopes are 10:1 or flatter (Illustration 3), the median barrier should be placed in the center of the median.



MEDIAN BARRIER PLACEMENT
(Sloped Medians)

Figure 10-10

2. For Cross Section II, the slope in the median will determine the proper treatment. If the slope is steeper than 10:1 but flatter than 3:1 (Illustration 4), the median barrier should be placed at "b". If the median slope is 3:1 or steeper, a roadside barrier at "b" is the only necessary treatment. If the median slope is a roadside hazard (e.g., rough rock cut) (Illustration 5), a roadside barrier should be placed at both "b" and "d". If the median slope is 10:1 or flatter (Illustration 6), the median barrier should be placed in the center of the median.

3. For Cross Section III (Illustration 7), the redirective capacity of the median slope will determine the proper treatment. If the median slope is 3:1 or steeper and 3 feet or higher, no roadside or median barrier is necessary. If the median slopes are flatter than 3:1, and/or not 3 feet high, the median barrier should be placed at the apex of the cross section. A rub rail should be placed on both sides of the barrier.

Flared/Divided Median Barriers

It may be necessary to intermittently divide a median barrier or to flare the barrier from one side to the other. The slope criteria or a fixed object in the median may require this. The median barrier may be divided by one of these methods:

1. A fixed object may be encased by a CMB.

2. A half-section CMB may be used on both sides to shield a fixed object.

3. The metal beam median barriers can be split into two separate runs of barrier passing on either side of the median hazard (fixed object or slope).

If a median barrier is split, the design should adhere to the acceptable flare rates. Desirably, the flare rate will be 50:1. The maximum flare rate for the CMB is 20:1; for the metal beam barriers, it is 15:1.

End Treatments

If the end of the median barrier is within the clear zone, an impact attenuator will be used. See Section 10-7. In addition, the designer may consider other end treatments described in the AASHTO *Roadside Design Guide* in special situations.

10-6.05 Glare Screens

Glare screens can be used in combination with median barriers to eliminate headlight glare from opposing traffic. The Department has not adopted specific warrants for the use of glare screens. The typical application, however, is on urban freeways with narrow medians and high traffic volumes. Another application is between on/off ramps at interchanges where the two ramps adjoin

each other. Here, the sharp radii of curvature and the narrow separation may make headlight glare especially bothersome. The designer should consider the use of glare screens at these sites.

Blocking headlight glare can be achieved in several ways, and several commercial glare screens are available. Considering both effectiveness and ease of maintenance, the paddle glare screen barrier may be the best choice.

Glare screens should be designed for a "cutoff angle" of 20°. This is the angle between the median centerline and the line of sight between two vehicles traveling in opposite directions. The glare screen should be designed to block the headlights of oncoming vehicles up to the 20° cutoff angle. On horizontal curves, the design cutoff angle should be increased to allow for the effect of the curvature on headlight direction. The criteria is:

$$\text{Cutoff Angle (in degrees)} = 20 + \frac{5729.58}{R} = 20 + D$$

Where: R = radius of curve (ft)
D = degree of curve

The designer should also evaluate the impact of a glare screen on horizontal sight distance on curves to the left. The screen could significantly reduce the available middle ordinate for stopping sight distance. See Section 5-2.06 for a discussion of sight distance at horizontal curves.

10-7 IMPACT ATTENUATORS

10-7.01 Warrants

Warrants for impact attenuators are the same as barrier warrants. Once a hazard is identified, the designer should first attempt to remove, relocate or make the hazard breakaway. If the foregoing is impractical, then an impact attenuator should be considered. Impact attenuators are most often installed to shield fixed-point hazards. Examples include exit gore areas (particularly on structures), bridge piers, non-breakaway sign supports and median barrier ends.

10-7.02 Types

The following impact attenuators are just three of the many that have been approved for use in Maine. For a complete, current listing of acceptable attenuators, refer to the FHWA website at

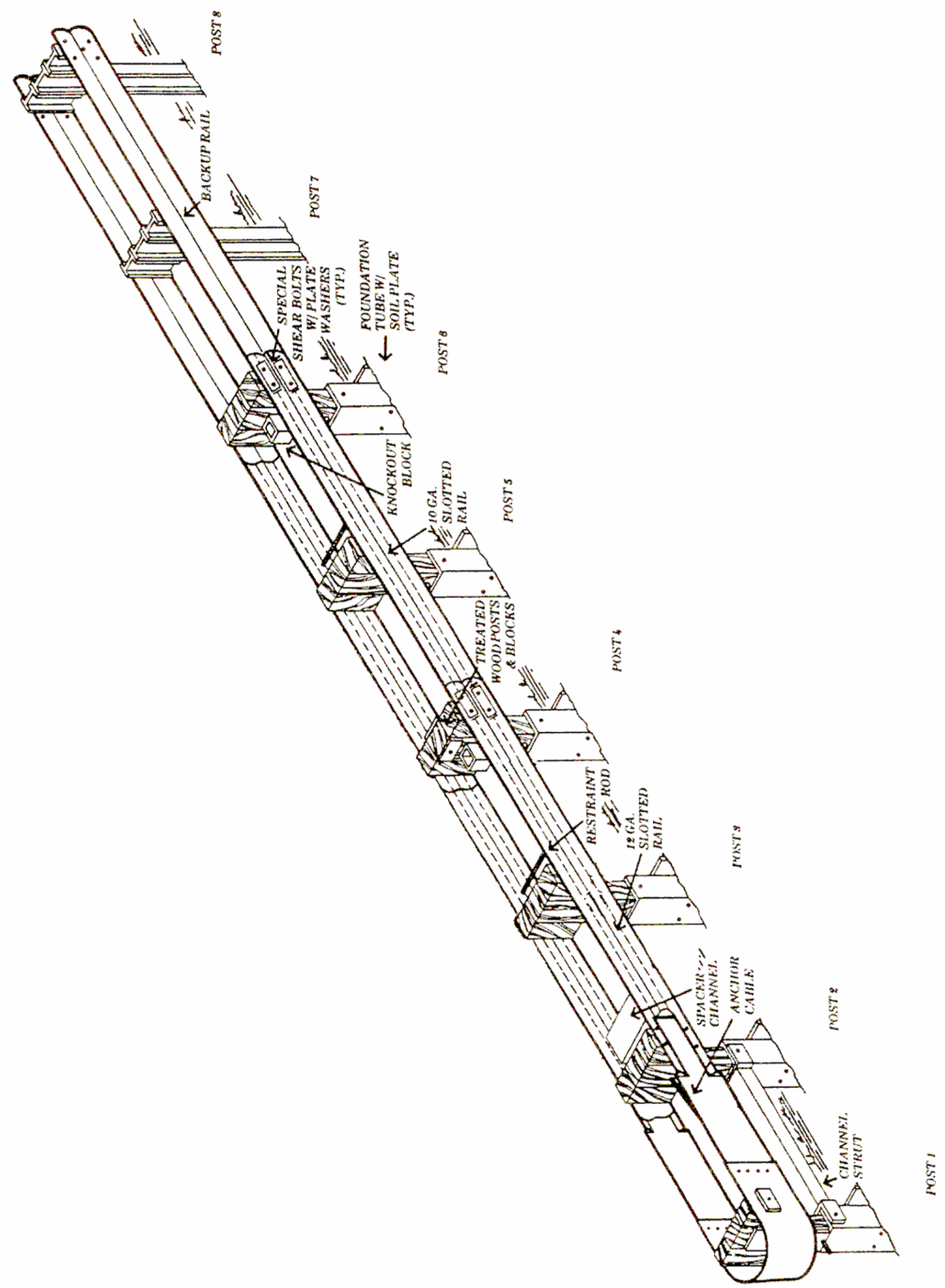
http://safety.fhwa.dot.gov/fourthlevel/hardware/term_cush.htm

The designer should note that each of these attenuators is patented. Selection shall be made on a case by case basis. Consideration should be given to space available and the likelihood of multi-directional hits.

1. CAT- 350**.** The Crash Cushion/Attenuating Terminal (CAT) uses energy absorbing beam elements, breakaway wooden posts and a cable anchorage system to gradually dissipate the vehicle's kinetic energy during impact. The system also provides adequate anchorage for the ends of double-beam guardrail and concrete median barriers. Figure 10-11 illustrates a typical design.

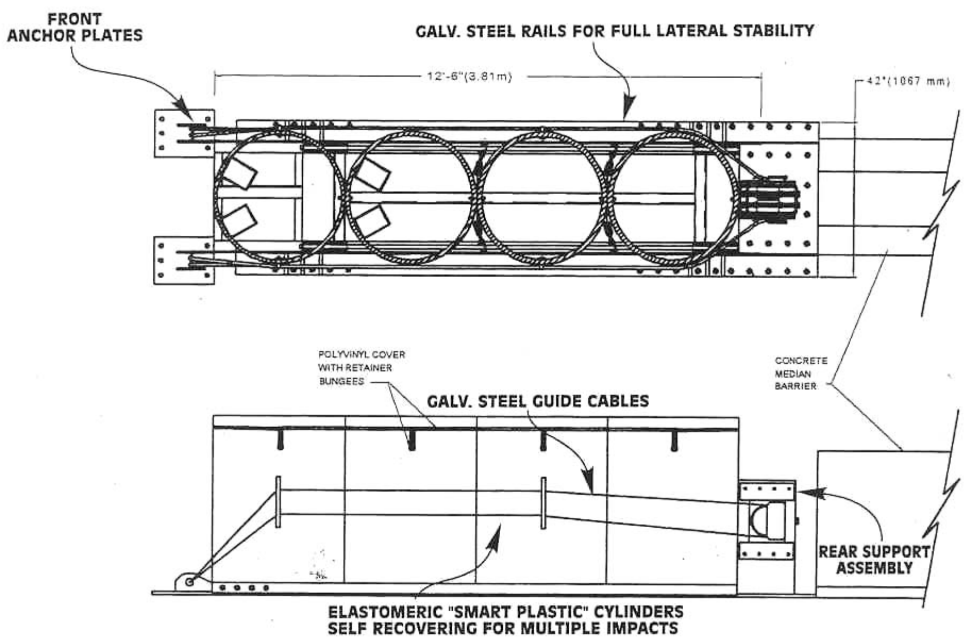
2. REACT - 350. The Reusable Energy Absorbing Terminal (REACT) uses plastic cylinders to provide safe deceleration for occupants in a vehicle. It is designed to withstand a series of impacts without need for major repairs. There are various cylinder arrangements possible for different situations. Figure 10-12 illustrates one of these arrangements.

3. QuadGuard. During head-on impacts, the QuadGuard Systems telescope rearward and crush the cartridges to absorb the energy of the impact. When impacted from the side, the QuadGuard Systems safely redirect the errant vehicle back toward its original travel path. Figure 10-13 illustrates different QuadGuard models for different uses.


POST 8
BACKUP RAIL
POST 7
SPECIAL SHEAR BOLTS W/ PLATE WASHERS (TYP.)
FOUNDATION TUBE W/ SOIL PLATE (TYP.)
POST 6
KNOCKOUT BLOCK
10 GA. SLOTTED RAIL
POST 5
TREATED WOOD POSTS & BLOCKS
POST 4
RESTRAINT ROD
12 GA. SLOTTED RAIL
POST 3
SPACER CHANNEL
ANCHOR CABLE
POST 2
CHANNEL STRUT
POST 1

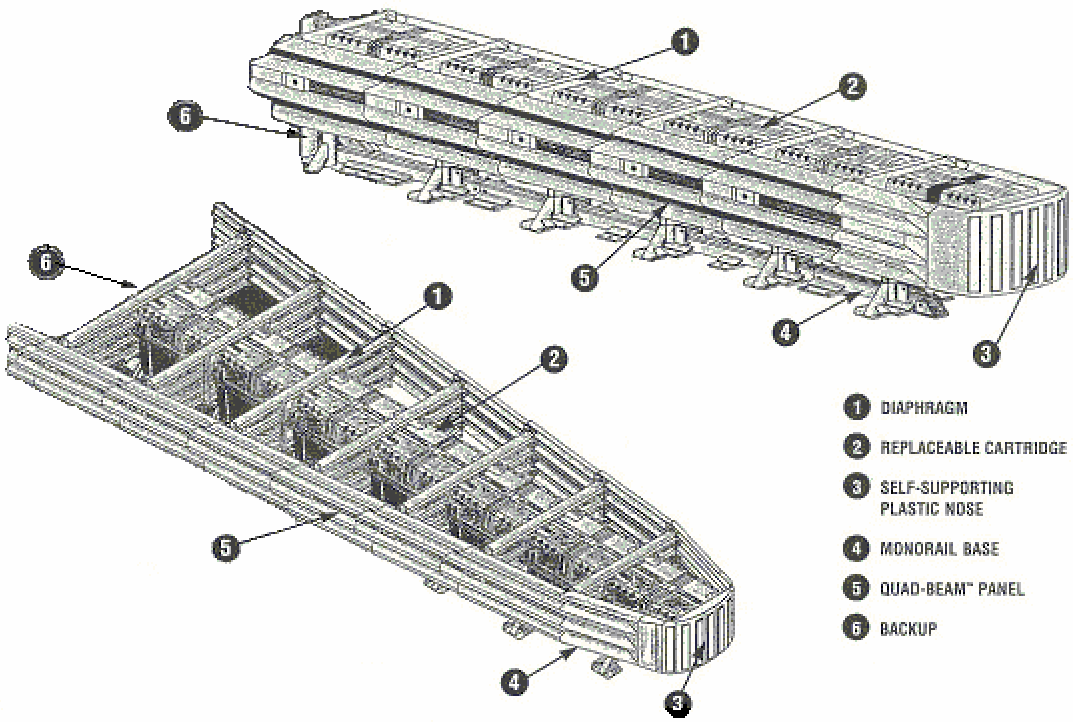
CAT-350

Figure 10-11



REACT-350

Figure 10-12



QuadGuard

Figure 10-13

In the future, other impact attenuator systems may be developed and approved for use by the Department.

10-7.03 Impact Attenuator Design

Once an impact attenuator has been selected, the designer must ensure that its design is compatible with the traffic and physical conditions at the site. For the patented attenuators, the designer should coordinate with the manufacturer for all design features.

Impact Speed

An initial impact speed must be assumed in selecting an attenuator. Table 10-8 presents the Department's criteria.

Highway Design Speed (V in mph)	Impact Speed (mph)	
	Freeways	***Non-Freeways***
$V \geq 60$	60	60
$40 < V < 60$	60	Design Speed
$V \leq 40$	-	40

IMPACT SPEED FOR IMPACT ATTENUATORS

Table 10-8

Deceleration

For impact attenuators, acceptable vehicular deceleration is determined by the criteria which has been adopted by FHWA. The manufacturer is responsible for ensuring that the system meets the FHWA deceleration criteria.

Placement

Several factors should be considered in the placement of an impact attenuator:

1. ***Level Terrain.*** The attenuator should be placed on a level surface or on a cross slope not to exceed 5 percent.

2. ***Curbs.*** No curbs should be present at proposed new installations.

3. ***Surface***. A paved, bituminous or concrete pad should be provided under the attenuator.

4. ***Orientation.*** The proper orientation angle will depend upon the design speed, roadway alignment and lateral offset distance to the cushion. For most roadside conditions, a maximum angle of approximately 10°, as measured between the highway and attenuator longitudinal centerlines, is considered appropriate.

CHAPTER ELEVEN

GEOMETRIC DESIGN OF EXISTING HIGHWAYS

Volume I

- Highway Design Guide –

National Standards

December 2004

Chapter Eleven

TABLE OF CONTENTS

Section Page

TABLE OF CONTENTS
(Continued)

Chapter Eleven

GEOMETRIC DESIGN OF EXISTING HIGHWAYS

11-1 GENERAL

11-1.01 Introduction

The overall objective of the Department's program is to improve the greatest number of existing highway miles within the available funds for highway projects. "Improve" is meant to apply to all aspects which determine a facility's serviceability, including:

1. the structural integrity of the pavement, bridges and culverts;

2. the drainage design of the facility to, among other objectives, minimize ponding on the highway, to protect the pavement structure from failure, and to prevent roadway flooding during the design-year storm;

3. from a highway capacity perspective, the level of service provided for the traffic flow;

4. the adequacy of access to abutting properties;

5. the geometric design of the highway to safely accommodate expected vehicular speeds and traffic volumes;

6. the roadside safety design to reduce, within some reasonable boundary, the adverse impacts of run-off-the-road vehicles; and

7. the traffic control devices to provide the driver with critical information and to meet driver expectancies.

The Department's responsibility is to realize the greatest overall benefit from the available funds. Therefore, on individual projects, some compromises may be necessary to achieve the goals of the overall highway program. Specifically for geometric design and roadside safety, the compromise is between what is desirable (new construction criteria for the National Highway System (NHS)) and what is practical for the specific conditions of each highway project.

The desirable criteria for highway design have been discussed in detail in Chapters Three through Ten. These criteria will apply to new construction and reconstruction on all NHS and major arterial projects. In response to the National Highway System Designation Act of 1995, the Department has adopted geometric design criteria for projects on all other highways projects that are, in many cases, lower than the criteria for NHS projects. These revised criteria are based on an assessment of the underlying principles behind geometric design and on how the criteria can be modified while still enhancing highway safety.

11-1.02 Background

On June 10, 1982, the FHWA issued its Final Rule entitled "Design Standards for Highways: Resurfacing, Restoration and Rehabilitation of Streets and Highways Other Than Freeways." This rule modified 23CFR Part 625 to adopt a flexible approach to the geometric design of 3R projects. Part 625 was modified again on March 31, 1983, to explicitly state that one objective of 3R projects is to enhance highway safety. In the rule FHWA determined that it is not practical to adopt 3R design criteria for nationwide application. Instead, each State can develop its own criteria and/or procedures for the design of 3R projects, subject to FHWA approval. This approach is in contrast to the application of criteria for new construction and major reconstruction, for which the AASHTO *A Policy on Geometric Design of Highways and Streets* provides national criteria for application.

In 1987, the Transportation Research Board published Special Report 214 *Designing Safer Roads; Practices for Resurfacing, Restoration and Rehabilitation*. The objective of the TRB study was to examine the safety cost-effectiveness of highway geometric design criteria and to recommend minimum design criteria for 3R projects on non-freeways. The final TRB report (SR214) presented specific numerical criteria for the geometric design of 3R projects.

On October 17, 1988, FHWA issued the, Technical Advisory T5040.28 "Developing Geometric Design Criteria and Processes for Non-Freeway RRR Projects." The purpose of the Advisory was to provide guidance on developing or modifying criteria for the design of Federal-aid, non-freeway 3R projects. The Advisory stated that each State may choose to develop and adopt geometric design criteria specifically for non-freeway 3R projects and that SR214 may be used as the basis for developing 3R criteria. The Department then developed its own criteria for the geometric design of 3R projects. The overall objective of the Department's criteria are summarized as follows:

1. 3R projects are intended to extend the service life of the existing facility and to return its features to a condition of structural or functional adequacy.

2. 3R projects are intended to enhance highway safety.

3. 3R projects are intended to incorporate cost-effective, practical improvements to the geometric design of the existing facility.

In 1995, the National Highway System Designation Act of 1995 was passed, allowing States to establish standards for all highway construction not on the NHS. The Department developed a set of standards for highway design in response to this Act. In 2000, a Task Force appointed by the Chief Engineer revisited these standards and developed new standards for Minor Collector highways. In July 2000, the State Standards Highway Design Guide was published. Currently, all Non-NHS highway projects of Minor Arterial classification or less are designed to these State Standards.

11-1.03 Application of Chapter Eleven

***NHS and Major Arterials*:** Chapter Eleven criteria should be used on Rehabilitation and Resurfacing projects. *If the scope of work includes more than 3000 feet of continuous full reconstruction, as allowed on rehabilitation projects, the criteria from Chapters Three through Ten should be used.* When a particular criterion is not addressed in Chapter Eleven, Chapters Three through Ten will apply.

***Other Non-NHS*:** The State Standards Highway Design Guide should be used on all projects. Chapter Eleven provides additional discussion that should compliment the State Standards. When a particular criterion is not addressed in the State Standards or Chapter Eleven, Chapters Three through Ten will apply.

11-1.04 Project Evaluation

These factors should be evaluated in the design of all projects on existing highways:

1. System or Functional Classification. The Department has adopted separate tables of geometric design criteria for all projects based on functional classification and urban/rural location.

2. Traffic Volumes. The designer should examine the current and projected traffic volumes within the limits of a project on an existing highway. This may influence the decisions on the extent of geometric improvements.

3. Pavement Condition. Projects are often programmed because of a significant deterioration of the existing pavement structure (including subbase, base and surface course). The extent of deterioration will determine the necessary level of pavement improvements. This decision will also influence the extent of practical geometric improvements.

4. Physical Characteristics. The physical constraints within the limits of a project on an existing highway will often determine what geometric improvements are practical and cost

effective. These include topography, adjacent development, available right-of-way, utilities and environmental constraints. The designer should also examine the geometric features and design speeds of highway sections adjacent to the proposed project to provide design continuity with the adjacent sections. This involves a consideration of factors such as driver expectancy, geometric design consistency and proper transitions between sections of different geometric designs.

5. Traffic Controls and Regulations. All signing and pavement markings on all projects must meet the criteria of the *Manual on Uniform Traffic Control Devices* (MUTCD). The Traffic Engineering Division is responsible for selecting and locating the traffic control devices on the project. The designer should work with Traffic to identify possible geometric and safety problems that will not be improved by the project and, therefore, may warrant traffic control devices.

6. Safety Enhancement. All projects on existing highways must be designed to consider and incorporate appropriate, practical safety improvements.

7. Crash Records. The historical accident data within the limits of a proposed project on an existing highway should be evaluated as part of the project development. Accident data is available from the Bureau of Planning, Research, and Community Services. The following accident data analyses may be appropriate:

   a. Accident Rate versus Statewide Average (for that type facility). This will provide an overall indication of safety problems within the project limits.

   b. Accident Analysis by Type. This will indicate if certain types of accidents are a particular problem; they may occur in disproportionate numbers. For example, a large number of head-on and/or sideswipe accidents on a two-lane facility may indicate inadequate roadway width. A large number of fixed object accidents may indicate an inadequate roadside clear zone.

   c. Treatment of High Hazard Locations and Features. Accidents may cluster about certain locations, such as a horizontal curve or intersection. In particular, the designer should check to see if any locations on the Department's list of High Accident Locations, as identified by the Department's accident data system, fall within the proposed project limits.

   If an accident problem is identified, the designer should evaluate the nature of the problem and identify candidate actions to reduce the accident problem. The designer may need to discuss the accident analysis with the Traffic Engineering Division, the Bureau of Planning, Research, and Community Services and/or the Maintenance

Division. Any selected accident countermeasures should be consistent with the overall scope of project.

8. Potential Impacts of Various Types of Improvements. Projects on existing highways may impact the social, environmental and economic nature of the surrounding land and development. In particular, the existing right-of-way may severely restrict the practical extent of geometric improvements.

9. Economics. Projects on existing highways are intended to preserve the service life of the existing highway system and to enhance highway safety. This will protect the economic investment and derive the maximum economic benefit from the Department's existing highway system. Therefore, economic factors (i.e., the cost of improvement versus the anticipated benefit) are a major consideration in determining which geometric design improvements are practical and reasonable.

11-2 RECONSTRUCTION PROJECTS (Non-Freeways)

11-2.01 Definition

Section 3-6 defines reconstruction projects on non-freeways as follows:

> *If a new pavement structure (from the subgrade on up) will be constructed for more than half of the project length, this will typically be considered a reconstruction project. Reconstruction of an existing non-freeway may also include significant drainage improvements, the addition of travel lanes and/or significant changes to the existing horizontal and vertical alignment, but essentially within the existing highway corridor. These projects will often require right-of-way acquisitions.*

Because of the extent of improvement, the design of a reconstruction project will be determined by the criteria for new construction. Therefore, on NHS and Major Arterials, the criteria in Chapters Three through Ten will apply to reconstruction projects. On all other projects, the State Standards Highway Design Guide will apply. See the Discussion in Section 11-1.03.

11-3 REHABILITATION PROJECTS (Non-Freeways)

11-3.01 Definition

Section 3-6 defines 3R projects (in general) and rehabilitation projects (specifically) on non-freeways as follows:

> *Rehabilitation projects may involve significant improvements to the pavement structure, including a new pavement structure (from the subgrade on up) for up to half of the project length. In general, rehabilitation projects warrant the consideration of more significant improvements to the geometric design than restoration/resurfacing projects. Right-of-way acquisition will usually be limited takings, easements and grading rights.*

For NHS and Major Arterial projects, the geometric design criteria for rehabilitation projects on non-freeways are presented in the following sections. On all other projects, the State Standards Highway Design Guide will apply. See the Discussion in Section 11-1.03.

11-3.02 Traffic Volume Controls

The following will apply to rehabilitation projects:

1. Design Year Traffic Volumes. The design year will be 20 years beyond the construction completion date for traffic analyses (AADT, design hourly volume, etc.) for NHS and Major Arterials but may be 12 years for all other highways.

2. Level of Service. Tables 11-3 to 11-6 provide the level-of-service criteria for rehabilitation projects.

3. Traffic Data. The designer should obtain from the Bureau of Planning, Research, and Community Services the traffic data necessary to determine the level of improvement.

4. Capacity Analysis. The analytical techniques in the *Highway Capacity Manual* will be used to conduct the capacity analysis.

11-3.03 Design Speed

In most cases, the existing posted speed limit, as measured over a significant length of highway, will be acceptable as the minimum design speed on rehabilitation projects. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

11-3.04 Grades

1. Maximum. Tables 11-3 to 11-6 present the Department's criteria for maximum grades on rehabilitation projects.

2. Minimum. On curbed streets, the minimum grade is 0.25 percent. On uncurbed facilities, there is no minimum grade.

11-3.05 Crest Vertical Curves

The Department's criteria for crest vertical curves on rehabilitation projects are based on providing stopping sight distance (SSD) to a 2-foot height of object. This is the AASHTO recommended height of object.

To determine the adequacy of SSD on existing crest vertical curves on rehabilitation projects, follow this procedure:

1. Calculate the available SSD from:

$$S = \sqrt{\frac{2158\,L}{A}} \qquad (S < L)$$

OR

$$S = \frac{L}{2} + \frac{1079}{A} \qquad (S > L)$$

where: S = available stopping sight distance, feet
L = existing length of crest vertical curve, feet
A = existing algebraic difference in grades, percent

2. Compare the available SSD to the criteria in Table 11-1. If the existing SSD does not meet these criteria, the designer should evaluate the practicality of flattening the crest vertical curve. This will be based on the accident history, traffic volumes, construction costs, etc.

Design Speed (mph)	Minimum Stopping Sight Distance (ft)
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730

STOPPING SIGHT DISTANCE

Table 11-1

3. If the decision is made to flatten the crest vertical curve, the following equations (based on a 2-foot height of object) can be used to calculate the length of the curve:

$$L = \frac{A S^2}{2158} \qquad (S < L)$$

$$L = 2S - \frac{2158}{A} \qquad (S > L)$$

Desirably, the crest vertical curve will be designed to meet the criteria for a 2-foot height of object (See Section 4-2.03).

11-3.06 Sag Vertical Curves

For rehabilitation projects, the Department has adopted the comfort criteria to evaluate the adequacy of existing sag vertical curves. To determine the adequacy of existing sag vertical curves on rehabilitation projects, follow this procedure:

1. Calculate the design speed of the existing sag from:

$$V = \sqrt{\frac{46.5 L}{A}}$$

where: V = design speed, mph
L = existing length of sag vertical curve, feet
A = existing algebraic difference in grades, percent

2. Compare the available design speed at the sag to the overall design speed for the project (see Section 11-3.03). If existing sag does not meet the comfort criteria, the designer should evaluate the practicality of flattening the curve. This will be based on accident history, traffic volumes, construction costs, etc.

3. If the decision is made to flatten the sag vertical curve, the following equation (based on the comfort criteria) can be used to calculate the length of the curve:

$$L = \frac{A\,V^2}{46.5}$$

Desirably, the sag vertical curve will be designed to meet the headlight sight distance criteria (see Section 4-2.03).

11-3.07 Horizontal Alignment

The horizontal alignment criteria in Chapter Five will apply to rehabilitation projects, except as discussed in the following.

Superelevation Rate/Degree of Curve

Table 5-6 will be used to determine the proper combination of superelevation rate and degree of curve based on the project design speed. The table is based on an e_{max} = 6.0%. If an existing curve has a superelevation rate steeper than 6 percent, an e_{max} = 8.0% will apply. The designer should reference the AASHTO *A Policy on Geometric Design of Highways and Streets* for combinations of superelevation rate and degree of curve where an e_{max} = 8.0% applies.

Reverse Curves

For reverse curves on rehabilitation projects, it will be acceptable to provide no tangent section between the curves (i.e., the PT & PC may be coincident). On Minor Arterials, the use of reverse curves is not preferred.

11-3.08 Cross Section Elements

Tables 11-3 to 11-6 present the Department's rehabilitation criteria for the width and steepness of cross section elements. The cross section width and/or steepness of the existing highway elements should be evaluated against the criteria in the rehabilitation tables. If the existing width or steepness does not meet the rehabilitation criteria, the designer should consider widening or flattening the element. If the decision is made to improve the cross section element, the designer should provide a value that at least meets the rehabilitation criteria. However, it may be appropriate to improve the cross section element(s) beyond the rehabilitation criteria.

Right-of-Way

As indicated in the basic definition of a "Rehabilitation Project," right-of-way acquisition will usually be limited takings, easements and grading rights. Occasionally, more extensive right-of-way involvement may be appropriate if, for example, a horizontal curve is flattened.

Curbs

On rehabilitation projects, the following will apply to the installation or retention of curbs:

1. Type. Where a project will disturb existing curbs, the curb will be replaced in-kind.

2. Height. Rehabilitation projects may include pavement work that will not affect the lateral location of existing curbs, but will affect their reveal. The designer will consider adjusting the curb reveal (or the pavement design) if:

    a. an analysis of the storm water flow in the gutter indicates overtopping the curb for the design parameters (e.g., design-year frequency, ponding on roadway); and/or

    b. the curb reveal after construction will be less than 3 inches.

Sidewalks

Where a rehabilitation project will disturb existing sidewalks, the sidewalk will be replaced in-kind. Where sidewalks do not currently exist, the need for sidewalks will be determined on a case-by-case basis. Sidewalks must meet Americans with Disabilities Act (ADA) regulations - see sidewalk policy.

Fill/Cut Slopes

Rehabilitation projects may include roadway widening. Tables 11-3 to 11-6 present the Department's criteria for fill and cut slopes on rehabilitation projects. If the slopes will be steeper than those in the tables, the designer should evaluate the practicality of flattening the fill/cut slopes considering the costs and impacts of corrective actions.

Bridges

The Urban and Federal Bridge Program will determine the acceptable roadway width for bridges to remain in place and for new and rehabilitated bridges within the limits of a rehabilitation project. The Urban and Federal Bridge Program will also evaluate the adequacy of existing bridge rails. The designer will be responsible for evaluating the adequacy of the existing guardrail transition approaching the bridge rail.

Transitions

When roadway transitions are required at bridge or underpass sections or at project termini, the length of transition (L) should be computed by the formula $L = WS$ for highways with a design speed greater than 45 mph. The formula $L = WS^2/60$ should be used to compute transitions on highways with a design speed of 45 mph and below. For both formulas, L equals the taper length in meters, W the offset distance in meters, and S the design speed in mph.

11-3.09 Intersections At-Grade

The criteria in Chapter Eight on the design of intersections at-grade will apply to any intersections within the limits of a rehabilitation project as modified by the following discussion.

Intersection Sight Distance (ISD)

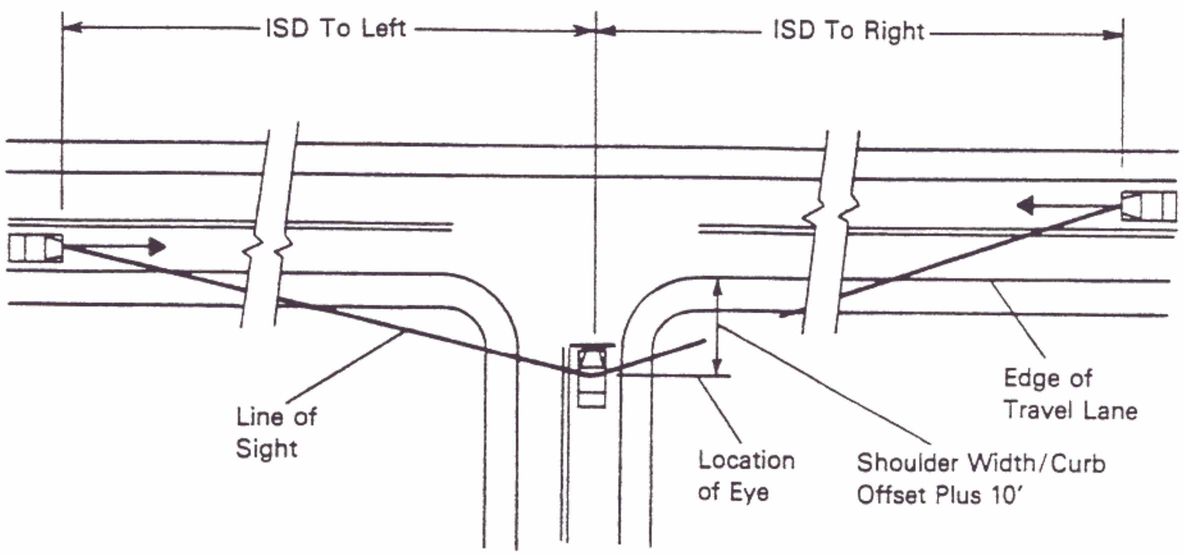
Section 8-1 presents ISD criteria based on the type of traffic control (no control, yield control, stop control or signal control). These criteria will apply to rehabilitation projects except for the ISD criteria at stop-controlled intersections. In this case, Figure 11-1 will apply. The desirable criteria are identical to the ISD criteria for new construction/reconstruction projects at stop-controlled intersections as presented in Section 8-1. The minimum criteria are based on ensuring that the driver on the mainline has (level) stopping sight distance available to the intersection assuming a 2-foot height of object.

Turning Radii Design

As described in Section 8-2, the turning radii design will be determined by the turning characteristics of a WB-62 design vehicle. For rehabilitation projects, the criteria for inside clearance are modified as follows. It is desirable that the WB-62 maintains approximately a 2-foot clearance from the pavement edge or curb line. At a minimum, the WB-62 may be allowed to make the right turn such that its wheels will almost touch the pavement edge or curb line. This means that the vehicle will overhang beyond the edge. Therefore, the designer must ensure that the turning vehicle will not impact any obstructions (signal poles, mailboxes, etc.).

Median Openings

As described in Section 8-6, the length of median opening will be determined by a WB-62 design vehicle making a left turn from the side road onto the divided facility. This will also apply to rehabilitation projects except for the criteria for inside clearance. It is desirable that the WB-62 maintains approximately a 2-foot clearance from the median nose. It is acceptable for the wheels of the vehicle to almost touch the edge of the median nose, assuming that the vehicular overhang will not impact any obstructions.



Design Speed (mph)		25	30	35	45	50	55	60	65
Sight Distance (ft)	***Desired***	280	335	390	500	555	610	665	720
	Minimum	155	200	250	360	425	495	570	645

Notes:

1. See Section 8-1 for more information
2. These are based on ensuring that the driver on the mainline (level) has adequate stopping sight distance available in advance of the intersection. To check for this distance, use an eye height of 3.5 ft and an object height of 2 ft for the vehicle on the mainline.

INTERSECTION SIGHT DISTANCE
(Stop Control for Rehabilitation Projects)

Figure 11-1

11-3.10 Roadside Safety

General Application

The Department should take the opportunity when designing the rehabilitation project to implement practical roadside safety improvements. The designer should review the roadside accident history to assist in the decision-making. The following discussion offers roadside safety criteria that apply specifically to rehabilitation projects.

Roadside Clear Zones

For rehabilitation projects on the NHS and Major Arterials, Table 11-2 presents the recommended clear zone distances. The procedures in Section 10-1 (e.g., clear zones across ditch sections) will apply, except that Table 11-2 will be the basis for the analysis. Tables in the State Standards Highway Design Guide will determine clear zones for all other rehabilitation projects. *The distances given there will be measured from edge of travelway and will include the slope.*

Once a hazard has been identified within the clear zone, the designer should consider the following:

1. Crash Records. The designer should review the accident data to estimate the extent of the roadside safety problem. In particular, there may be sites where clusters of run-off-the-road accidents have occurred (e.g., on the outside of horizontal curves).

2. Location Relative to Clear Zone Distance. The closer an obstacle is to the traveled way, the greater the potential benefits of treatment. It is less likely to be cost effective to treat a hazard near the outer edge of the clear zone boundary.

3. Location Relative to Other Hazards. If a hazard is one of many at about the same distance from the traveled way, this decreases the benefits of treatment. As an example, it may have little benefit to remove an obstacle 12 feet from the travel lane if a line of other obstacles (e.g., trees) are located at 15 feet from the travel lane. However, it may be beneficial to treat an isolated hazard along the roadside that is within the clear zone distance.

4. Treatment Costs. A hazard may be removed, relocated or made breakaway. The costs of these treatments will be a significant factor in the decision-making process.

5. Nature of Hazard. The type of hazard and the available treatments will be a significant factor in the decision-making process. For example, a non-breakaway signpost, which is owned and maintained by the Department, can be made breakaway without any impact on the surrounding environment. However, removing natural features (e.g., trees) may impact the environment and may meet with strong public opposition.

REHABILITATION PROJECTS

Design Speed (mph)	Design AADT **	Fill Slopes			Cut Section With Ditch Figure10-1(E) ***
		Recoverable (Figure 10-1(A))		Recoverable (Figure 10-1(A)) ***	
		1:6 or Flatter	1:5 to 1:4		
40 or Less	Under 750 750 - 1500 1500 - 6000 Over 6000	5 - 7 7 - 8 8 - 9 9 - 11	5 - 7 8 - 9 9 - 11 11 - 12	SEE PROCEDURE IN SECTION 10-1.03	SEE PROCEDURE IN SECTION 10-1.04
45 - 50	Under 750 750 - 1500 1500 - 6000 Over 6000	7 - 8 9 - 11 11 - 12 13 - 15	8 - 9 11 - 13 13 - 18 16 - 19		
55	Under 750 750 - 1500 1500 - 6000 Over 6000	8 - 9 11 - 12 13 - 15 15 - 16	9 - 12 13 - 16 16 - 20 17 - 21*		
60	Under 750 750 - 1500 1500 - 6000 Over 6000	11 - 12 13 - 16 17 - 20 20 - 22*	14 - 16 17 - 21* 21 - 27* 24 - 30*		
65 - 70	Under 750 750 - 1500 1500 - 6000 Over 6000	12 - 13 16 - 17 19 - 21* 20 - 23*	13 - 17 19 - 24* 23 - 28* 26 - 31*		

* *On non-freeways, the clear zone distance may be limited to 20 feet for practicality and to provide a consistent roadway template.*

** *Use the AADT projected for the design year for the overall project.*

*** *See the discussion in Section 11-3.10 and Chapter Ten.*

RECOMMENDED CLEAR ZONE DISTANCES
(In Feet Measured from Edge of Travel Lane)

Table 11-2

6. Utilities. Utility poles are a common roadside obstacle on rehabilitation projects. Relocation is mandatory when the utility poles physically interfere with construction or when their placement is inconsistent with the Department's "Policy on Above Ground Utility Locations." Relocation for safety benefits must be evaluated on a case-by-case basis.

7. Barrier Protection. The designer should realize that the barrier warrants presented in Section 10-2 are based on the relative severity between hazard and guardrail; they do not address the question of whether or not a barrier installation is cost-effective. On rehabilitation projects, the designer must judge whether or not a barrier should be installed when a hazard is within the clear zone and will be left in place.

Roadside clear zones are a controlling design element. For the purpose of determining when a design exception is necessary on a rehabilitation project, the following will apply:

1. Parallel Fill Slopes. The criteria in Table 11-2 or the State Standards Highway Design Guide will determine the applicable clear zone distance. However, where fill slopes are 1:4 or flatter, a maximum distance of 20 feet from the edge of travel lane will apply for design exceptions on rehabilitation projects. On fill slopes steeper than1:4 and where the applicable clear zone extends beyond the toe of the slope, the clear zone distance will be to the toe of the slope for design exceptions. It is desirable to provide a 10 feet clear zone beyond the toe.

2. Horizontal curves. The horizontal curvature correction in Section 10-1.05 will not apply for the purpose of determining when a design exception is necessary.

Safety Appurtenances

During the design of a rehabilitation project, all existing safety appurtenances should be examined to determine if they meet the latest safety performance and design criteria. This includes guardrail, impact attenuators, median barriers, sign supports, luminaire supports and bridge rail transitions. All safety appurtenances should be upgraded to meet the most recent design criteria. Chapter Ten presents the Department's criteria for the layout and design of safety appurtenances.

Roadside barrier warrants on rehabilitation projects can be especially difficult to resolve. The designer should evaluate the roadside environment against the criteria in Chapter Ten. Basically, the process will be:

1. Determine if barrier is warranted based on Chapter 10 criteria.

2. If an existing run of barrier is located where no barrier is warranted, remove the guardrail.

3. If barrier is warranted, consider removing or relocating the hazard; reducing its severity (e.g., flattening a slope); or making it breakaway.

4. If the hazard cannot be eliminated and a barrier is judged to be cost effective, then install guardrail. The designer should recognize that, depending on the specific site conditions, it may be acceptable to identify a hazard within the applicable clear zone and leave the hazard unshielded. A decision on the cost-effectiveness of barrier installation will be based on construction costs, traffic volumes, accident history, barrier adaptability to the site, etc.

5. For existing runs of guardrail which will remain, ensure that they meet, as practical, the applicable performance and design criteria, including:
   a. operational acceptability (hardware, height, etc.);
   b. dynamic deflection criteria;
   c. length of need;
   d. lateral placement;
   e. placement on slopes and behind curbs; and
   f. end treatments.

Existing and proposed guardrail installations on rehabilitation projects will, in some cases, cause special problems. These include:

1. Guardrail Height. A common problem on rehabilitation projects will be the guardrail height of existing installations because of pavement overlay or pavement rehabilitation. Each existing run that will remain must be considered individually. As a general rule, the designer should seriously consider raising the guardrail when its height, after construction, will be more than 3 inches below the recommended height.

2. Slopes in Front of Barrier. It will be acceptable to retain existing installations on 1:6 or flatter slopes where the installation is otherwise acceptable. Existing barrier installations may have terminal sections that flare away and terminate on a slope steeper than 1:10, but flatter than or equal to 1:6. If no other barrier deficiencies exist, it will be acceptable to leave the existing installation in place. Where a flared section crosses a ditch section, it may be necessary to place a small pipe and regrade through the ditch to meet this criteria.

11-3.11 Tables of Geometric Design Criteria

Tables 11-3 to 11-6 present the criteria for the geometric design of rehabilitation projects on non-freeways. A separate table is presented for the arterial and collector functional classes in urban and rural locations.

11-3.12 Design Exception Process

The discussion in Section 3-7 on exceptions applies equally to the geometric design of rehabilitation projects. The only difference, obviously, is that the designer will be evaluating the proposed design against the criteria presented in Section 11-3 or the State Standards Highway Design Guide.

Design Element				Manual Section **	2 - Lane: Under 750	2 - Lane: 750 - 2000	2 - Lane: Over 2000	Multilane: Divided	Multilane: Undivided
		Design Year AADT (1)							
DESIGN CONTROLS	*Design Speed (3)			3-4	Posted Speed Limit			Posted Speed Limit	
	Access Control			3-5	Entrance Control			Entrance Control	
	Level of Service			3-3	Desirable:C Minimum: D			Desirable:C Minimum: D	
CROSS SECTION ELEMENTS	*Lane Width			6-1	11'	Des:12' Min: 11'		Desirable:12' Minimum: 11'	
	*Shoulder Width (4)	Right		6-1	4'		6'	8'	
		Left		6-1	N/A			4'	N/A
	Cross Slope	*Travel Lane		6-1	2.0%			2.0%	
		Shoulder (5)		6-1	4.0%			4.0%	
	Auxiliary Lane Width (6)			6-1	Desirable:12' Minimum: 10'			Desirable:12' Minimum: 10'	
	Median Width			6-2	N/A			Existing	N/A
	*New and Rehabilitated Bridges	Structural Capacity		~	**SEE BRIDGE PROGRAM**			**SEE BRIDGE PROGRAM**	
		Minimum Width		~					
	*Existing Bridges to Remain in Place	Structural Capacity		~					
		Minimum Width		~					
	Clear Zone			10-1	(7)			(7)	
	Side Slopes	Cut	Front Slope	6-3	1:3 or Flatter (10)		1:4	1:4	
			Depth of Ditch	6-3	(8)			(8)	
			Back Slope	6-3	1:2 (9)			1:2 (9)	
		Fill	0 - 15' Height	6-3	1:3 or Flatter (10)		1:4 (10)	1:4 (10)	
			> 15' Height	6-3	1:2 (11)			1:2 (11)	
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (12)			4-1	50 mph	55 mph		60 mph	
					425'	495'		570'	
	Passing Sight Distance			4-1	1835'	1985'		2135'	
	Decision Sight Distance (13)			4-1	750'	865'		990'	
	*Maximum Degree of Curve (e = 6.0%)			5-2	6° 45'	5° 15'		4° 15'	
	*Superelevation Rate			5-2	e_{max} = 6.0%/8% (14)				
	*Horizontal Sight Distance			5-2	(15)				
	*Maximum Profile Grades (16)	Level		4-2	6%	6%		5%	
		Rolling		4-2	7%	7%		6%	
		Mountainous		4-2	9%	8%		8%	
	Minimum Profile Grades			4-2	Desirable: 0.25%			Minimum: 0%	
	*Minimum Vertical Clearance (17)	New and Replaced Overpassing Bridges		4-3	Desirable: 16'-6"			Minimum: 16'-0"	
		Existing Overpassing Bridges		4-3	14'-0"				

* Controlling design criteria (See Section 3-7)

**See Section 11-3 for specific discussion on rehabilitation projects

GEOMETRIC DESIGN CRITERIA FOR NHS AND MAJOR RURAL ARTERIALS
(Rehabilitation Projects)

Table 11-3

GEOMETRIC DESIGN CRITERIA FOR NHS AND MAJOR RURAL ARTERIALS
(Rehabilitation Projects)

Footnotes to Table 11-3

1. Design Year AADT. Desirably, the design year AADT will be 20 years beyond the construction completion date.

2. Multilane Facilities. The criteria in the table for the rehabilitation of multilane facilities will apply:

   a. to an existing multilane facility, or
   b. to an existing 2-lane facility which will become one half of a divided highway.

   In the case of "b", the new half of the divided facility will be designed according to the Department's new construction criteria. See Table 7-2.

3. Design Speed. In most cases, the existing posted speed limit will be acceptable as the minimum design speed. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

4. Shoulder Width (Curbed Facilities). On rural arterials where curbs are provided, it is desirable to increase a proposed 4' or 6' shoulder by an additional 2'. Proposed 8' or 10' shoulders do not need to be adjusted when curbs are introduced.

5. Shoulder Cross Slope. In most cases, the shoulder will be paved. In certain situations, 2.0 % cross slopes are permitted. If an existing unpaved shoulder will remain, the shoulder cross slope will be 6.0%.

6. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 2'.

7. Clear Zone. Clear zones will vary according to design speed, traffic volumes and side slope. See Section 11-3 for clear zones on rehabilitation projects.

8. Depth of Ditch. A "V" ditch section should be used unless hydraulic capacity warrants the use of a trapezoidal ditch. It is desirable to maintain the depth of ditch 1' below the subgrade.

9. Back Slope. For 1:4 front slopes, the typical practice is to place the toe of the back slope beyond the clear zone. In rock cuts, the back slope may be as steep as 4:1. See rock cut detail in Figure 6-12. In most cases, however, an existing rock cut will not be altered as part of a rehabilitation project.

10. Fill Slopes (0 – 15' Height). If guardrail is warranted for reasons other than the fill slope, use a 1:2 slope in combination with the guardrail rather than a 1:3 or 1:4 slope.

11. Fill Slopes (Height > 15'). A 1:1 slope is acceptable to avoid significant right-of-way and/or environmental concerns, however this will require geotechnical consideration.

12. Minimum Stopping Sight Distance. See Section 11-3 for a discussion on the application of the stopping sight distance to crest and sag vertical curves on rehabilitation projects.

13. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

14. Superelevation Rate. Where an e_{max} = 6.0% applies, use Table 5-6 to determine the superelevation rate. Where an e_{max} = 8.0% applies, see the AASHTO *A Policy on Geometric Design of Highways and Streets* to determine the superelevation rate.

15. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and required sight distance (see Section 5-2).

16. Maximum Grades. Grades 1 percent steeper may be used on one-way downgrades on divided facilities.

17. Minimum Vertical Clearance. The vertical clearances apply to the arterial passing under. For the 16'-6" clearance, 6" is provided for future resurfacing. The minimum vertical clearance is 17'-6" for the arterial passing under a new sign truss, and 17'-0" for the arterial passing under an existing sign truss. A 22'-6" (±6") clearance, depending on site conditions, is required at railroad underpasses beneath the arterial.

    Note that "existing overpassing bridges" refers to any bridge work, which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Urban and Federal Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

	Design Element		Design Year AADT (1)	Manual Section **	All Traffic Volumes					
DESIGN CONTROLS	*Design Speed (3)			3-4	Posted Speed Limit					
	Access Control			3-5	Entrance Control					
	Level of Service			3-3	Desirable: C			Minimum: D		
CROSS SECTION ELEMENTS	*Lane Width			6-1	11'					
	*Shoulder Width (3)			6-1	4'					
	Cross Slope		*Travel Lane	6-1	2.0%					
			Shoulder (5)	6-1	Paved: 4.0%, 2.0% allowable			Unpaved: 6.0%		
	Auxiliary Lane Width (4)			6-1	Desirable: 11'			Minimum: 10'		
	*New and Rehabilitated Bridges		Structural Capacity	~	**SEE BRIDGE PROGRAM**			**SEE BRIDGE PROGRAM**		
			Minimum Width	~						
	*Existing Bridges to Remain in Place		Structural Capacity	~						
			Minimum Width	~						
	Clear Zone			10-1	(5)					
	Side Slopes	Cut	Front Slope	6-3	1:3					
			Depth of Ditch	6-3	(6)					
			Back Slope	6-3	1:2 (7)					
		Fill	0 - 15' Height	6-3	1:3 (110					
			> 15' Height	6-3	1:2 (9)					
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (10)			4-1	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
					200'	250'	305'	360'	425'	495'
	Passing Sight Distance			4-1	1090'	1280'	1470'	1625'	1835'	1985'
	Decision Sight Distance (13)			4-1	450'	525'	600'	675'	750'	865'
	*Maximum Degree of Curve (e = 6.0%)			5-2	21° 00'	15° 00'	11° 15'	8° 45'	6° 45'	5° 15'
	*Superelevation Rate			5-2	e_{max} = 6.0%/8.0% (12)					
	*Horizontal Sight Distance			5-2	(13)					
	*Maximum Profile Grades		Level	4-2	9%	9%	9%	9%	8%	8%
			Rolling	4-2	11%	10%	10%	10%	9%	9%
			Mountainous	4-2	12%	12%	12%	12%	11%	11%
	Minimum Profile Grades			4-2	Desirable: 0.25%			Minimum: 0%		
	*Minimum Vertical Clearance (14)		New and Replaced Overpassing Bridges	4-3	Desirable: 15'-6"			Minimum: 15'-0"		
			Existing Overpassing Bridges	4-3	14'-0"					

* Controlling design criteria (See Section 3-7)

**See Section 11-3 for specific discussion on rehabilitation projects

GEOMETRIC DESIGN CRITERIA FOR
NON-NHS MINOR ARTERIAL AND COLLECTOR ROADS
(Rehabilitation Projects)

Table 11-4

GEOMETRIC DESIGN CRITERIA FOR NON-NHS MINOR ARTERIAL AND COLLECTOR ROADS (Rehabilitation Projects)

Footnotes to Table 11-4

1. Design Year AADT. Desirably, the design year AADT will be 20 years beyond the construction completion date. On rehabilitation, the design year may be 12 years beyond the construction completion date.

2. Design Speed. In most cases, the existing posted speed limit will be acceptable as the minimum design speed. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

3. Shoulder Width (Curbed Facilities). On rural collectors where curbs are provided, it is desirable to increase a proposed 4' or 6' shoulder by an additional 2'.

4. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 2'.

5. Clear Zone. Clear zones will vary according to design speed, traffic volumes and side slope. See the State Standards Highway Design Guide for clear zone requirements.

6. Depth of Ditch. A "V" ditch section should be used unless hydraulic capacity warrants the use of a trapezoidal ditch. It is desirable to maintain the depth of ditch 0.3 m below the subgrade.

7. Back Slope. In rock cuts, the back slope may be as steep as 4:1. See rock cut detail in Figure 6-12. In most cases, however, an existing rock cut will not be altered as part of a rehabilitation project.

8. Fill Slopes (0-15'Height). If guardrail is warranted for reasons other than the fill slope, use a 1:2 slope in combination with the guardrail rather than a 1:3 or flatter slope.

9. Fill Slope (Height > 15'). A 1:1 slope is acceptable to avoid significant right-of-way and/or environmental concerns, however this will require geotechnical consideration.

10. Minimum Stopping Sight Distance. See the State Standards Highway Design Guide and Section 11-3 for a discussion on the application of the stopping sight distance to crest and sag vertical curves on rehabilitation projects.

11. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

12. Superelevation Rate. Where an e_{max} = 6.0% applies, use Table 5-6 to determine the superelevation rate. Where an e_{max} = 8.0% applies, see the AASHTO *A Policy on Geometric Design of Highways and Streets* to determine the superelevation rate.

13. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and required sight distance (see Section 5-2).

14. Minimum Vertical Clearance. The vertical clearances apply to the collector passing under. For the 15'-6" clearance, 6" is provided for future resurfacing. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the collector.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Urban and Federal Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

Design Element			Manual Section **	2-Lane		Multi-lane (Divided/Undivided) (1)	
				With Curb	Without Curb	With Curb	Without Curb
DESIGN CONTROLS	* Design Speed (3)		3-4	Posted Speed Limit		Posted Speed Limit	
	Access Control		3-5	Entrance Control		Entrance Control	
	Level of Service		3-3	Desirable:C Minimum: D		Desirable:C Minimum: D	
	On-Street Parking		6-1	(3)		(3)	
CROSS SECTION ELEMENTS	*Lane Width		6-1	Desirable: 12' Minimum: 11'		Desirable: 12' Minimum: 11'	
	*Shoulder Width/Curb Offset	Right	6-1	6'	4'	Des: 2' Min: 1'	Des: 6' Min: 4'
		Left	6-1	N/A		1'	Des: 6' Min: 4'
	Cross Slope	*Travel Lane	6-1	2.0%		2.0%	
		Shoulder/Curb Offset (4)	6-1	4.0%, 2.0% allowable		4.0%, 2.0% allowable	
	Auxiliary Lane Width (5)		6-1	Desirable: 12' Minimum: 10'		Desirable: 12' Minimum: 10'	
	CTWLT Lane Width (6)		8-5	Desirable: 12' Minimum: 11'		Desirable: 12' Minimum: 11'	
	Parking Lane Width (7)		6-1	Desirable: 10' Minimum: 7'		Desirable: 10' Minimum: 7'	
	Sidewalk Width (8)		6-1	5' Minimum		5' Minimum	
	Median Width		6-2	N/A		Existing	
	*New and Rehabilitated Bridges	Structural Capacity	~	**SEE BRIDGE PROGRAM**		**SEE BRIDGE PROGRAM**	
		Minimum Width	~				
	*Existing Bridges to Remain in Place	Structural Capacity	~				
		Minimum Width	~				
	Clear Zone		10-1	1' Min.	(9)	1' Min.	(9)
	Side Slopes		6-3	See Figure 6-11	See Table 11-4	See Figure 6-10	See Table 11-4
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (10)		4-1	35 mph	40 mph	45 mph	50 mph
				250'	305'	360'	425'
	Passing Sight Distance		4-1	1280'	1470'	1625'	1835'
	Decision Sight Distance (11)		4-1	720'	825'	930'	1030'
	*Maximum Degree of Curve		5-2	16° 30' (e_{max} = 4.0%)	11° 30' (e_{max} = 4.0%)	8° 45' (e_{max} = 6.0%)	6° 45' (e_{max} = 6.0%)
	*Superelevation Rate		5-2	Fig. 5-11 (e_{max} = 4.0%)		e_{max} = 6.0%/8.0% (12)	
	*Horizontal Sight Distance		5-2	(13)			
	*Maximum Profile Grades	Level	4-2	10%	9%	8%	8%
		Rolling	4-2	11%	10%	9%	9%
		Mountainous	4-2	13%	12%	11%	11%
	Minimum Profile Grades		4-2	Curbed: Desirable~0.5%; Min.~0.25%		Uncurbed: Desirable~0.25%; Min.~0%	
	*Minimum Vertical Clearance (14)	New and Replaced Overpassing Bridges	4-3	Desirable: 16'-6"		Minimum: 16'-0"	
		Existing Overpassing Bridges	4-3	14'-0"			

* Controlling design criteria (See Section 3-7)

**See Section 11-3 for specific discussion on rehabilitation projects

GEOMETRIC DESIGN CRITERIA FOR URBAN NHS AND MAJOR ARTERIALS
(Rehabilitation Projects)

Table 11-5

GEOMETRIC DESIGN CRITERIA FOR URBAN NHS AND MAJOR ARTERIALS
(Rehabilitation Projects)

Footnotes to Table 11-5

1. Multilane Facilities. The criteria in the table for the rehabilitation of multilane facilities will apply to:

   a. an existing multilane facility, or
   b. an existing 2-lane facility which will become one half of a divided highway.

   In the case of "b", the new half of the divided facility will be designed according to the Department's new construction criteria. See Table 7-5.

2. Design Speed. In most cases, the existing posted speed limit will be acceptable as the minimum design speed. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

3. On-Street Parking. The decision to provide on-street parking will be made on a case-by-case basis. See Section 6-1 for more information.

4. Cross Slope (Curb Offset). For curb offsets (shoulder width less than 4'), the cross slope will be the same as the cross slope of the adjacent travel lane.

5. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 2'.

6. CTWLT Lane Width. In industrial areas with large truck traffic turning frequently, the desirable CTWLT lane width is 14'.

7. Parking Lanes. Where the parking lane will be used as a travel lane during peak hours or may be converted to a travel lane in the future, the width should be 11'. Cross slope for parking lanes should be 4.0%.

8. Sidewalk Width. Where roadside appurtenances are located within the sidewalk, the minimum width should be 7'. In built-up areas, the sidewalk is often paved between the curb and building line.

9. Clear Zone. Clear zones will vary according to design speed, traffic volumes and side slope. See the State Standards Highway Design Guide for clear zone requirements.

10. Minimum Stopping Sight Distance. See Section 11-3 for a discussion on the application of the stopping sight distance to crest and sag vertical curves on rehabilitation projects.

11. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

12. Superelevation Rate. Where an e_{max} = 6.0% applies, use Table 5-6 to determine the superelevation rate. Where an e_{max} = 8.0% applies, see the AASHTO *A Policy on Geometric Design of Highways and Streets* to determine the superelevation rate.

13. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the radius of curve and required sight distance (see Section 5-2).

14. Minimum Vertical Clearance. The vertical clearances apply to the arterial passing under. For the 16'-6" clearance, 6" is provided for future resurfacing. The minimum vertical clearance is 17'-6" for the arterial passing under a new sign truss, and 17-0" for the arterial passing under an existing sign truss. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the arterial.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Urban and Federal Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

	Design Element		Manual Section **	With Curb		Without Curb	
DESIGN CONTROLS	* Design Speed (3)		3-4	Posted Speed Limit			
	Access Control		3-5	Entrance Control			
	Level of Service		3-3	Desirable: C		Minimum: D	
	On-Street Parking		6-1	(2)			
CROSS SECTION ELEMENTS	*Lane Width (3)		6-1	Minimum: 11'			
	*Shoulder Width/Curb Offset (4)		6-1	6'		4'	
	Cross Slope	*Travel Lane	6-1	2.0%			
		Shoulder/Curb Offset (5)	6-1	4.0%, 2.0% allowable			
	Auxiliary Lane Width (6)		6-1	Desirable: 11'		Minimum: 10'	
	Parking Lane Width (7)		6-1	Desirable: 10'		Minimum: 7'	
	Sidewalk Width (8)		6-1	5' Minimum			
	*New and Rehabilitated Bridges	Structural Capacity	~	SEE BRIDGE PROGRAM		SEE BRIDGE PROGRAM	
		Minimum Width	~				
	*Existing Bridges to Remain in Place	Structural Capacity	~				
		Minimum Width	~				
	Clear Zone		10-1	Minimum: 1'		See Table 11-5	
	Side Slopes		6-3	See Figure 6-11		See Table 11-5	
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (10)		4-1	25 mph	30 mph	35 mph	40 mph
				155'	200'	250'	305'
	Passing Sight Distance		4-1	900'	1090'	1280'	1470'
	Decision Sight Distance (11)		4-1	540'	620'	720'	825'
	*Maximum Degree of Curve (e = 4.0%)		5-2	40° 00'	24° 45'	16° 30'	11° 30'
	*Superelevation Rate		5-2	Figure 5-11 (e_{max} = 4.0%)			
	*Horizontal Sight Distance		5-2	(12)			
	*Maximum Profile Grades	Level	4-2	11%	11%	11%	10%
		Rolling	4-2	14%	13%	12%	11%
		Mountainous	4-2	15%	14%	14%	13%
	Minimum Profile Grades		4-2	Desirable~0.25%; Min.~0%			
	*Minimum Vertical Clearance (13)	New and Replaced Overpassing Bridges	4-3	Desirable: 15'-6"		Minimum: 15'-0"	
		Existing Overpassing Bridges	4-3	14'-0"			

* Controlling design criteria (See Section 3-7)

**See Section 11-3 for specific discussion on rehabilitation projects

GEOMETRIC DESIGN CRITERIA FOR
URBAN NON-NHS MINOR ARTERIAL AND COLLECTOR ROADS/STREETS
(Rehabilitation Projects)

Table 11-6

GEOMETRIC DESIGN CRITERIA FOR URBAN NON-NHS MINOR ARTERIAL AND COLLECTOR ROADS/STREETS (Rehabilitation Projects)

Footnotes to Table 11-6

1. Design Speed. In most cases, the existing posted speed limit will be acceptable as the minimum design speed. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

2. On-Street Parking. The decision to provide on-street parking will be made on a case-by-case basis. See Section 6-1 for more information.

3. Lane Widths. In industrial areas, lanes should be 11’ wide.

4. Shoulder Width. On facilities with curbs, a minimum offset of 2’ between the edge of travel lane and curb may be used in restricted locations. However, the minimum curb-to-curb width is 26’.

5. Cross Slope (Curb Offset). For curb offsets (shoulder width less than 4’), the cross slope will be the same as the cross slope of the adjacent travel lane.

6. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 2’desirable and 1’ minimum.

7. Parking Lanes. Where the parking lane will be used as a travel lane during peak hours or may be converted to a travel lane in the future, the width should be 11’. Cross slopes for parking lanes should be 4.0%.

8. Sidewalk Width. Where roadside appurtenances are located within the sidewalk, the minimum width should be 7’. In built-up areas, the sidewalk is often paved between the curb and building line.

9. Clear Zone. Clear zones will vary according to design speed, traffic volumes and side slope. See the State Standards Highway Design Guide for clear zone requirements.

10. Minimum Stopping Sight Distance. See the State Standards Highway Design Guide and Section 11-3 for a discussion on the application of the stopping sight distance to crest and sag vertical curves on rehabilitation projects.

11. Decision Sight Distance. The values provided are for a directional change (e.g., lane change) at the design speed. See Section 4-1 for decision sight distance values for other conditions.

12. Horizontal Sight Distance. For a given design speed, the necessary middle ordinate should be determined by the degree of curve and required sight distance (see Section 5-2).

13. Minimum Vertical Clearance. The vertical clearances apply to the collector passing under. For the 15’-6” clearance, 6” is provided for future resurfacing. A 22’-6” (±6”) clearance, depending on actual site conditions, is required at railroad underpasses beneath the collector.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Urban and Federal Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

11-4 RESTORATION/RESURFACING PROJECTS (Non-Freeways)

11-4.01 Definition

Section 3-6 defines 3R projects (in general) and restoration/resurfacing projects (specifically) on non-freeways as follows:

> *Restoration/resurfacing projects are usually intended to resurface the existing pavement. Geometric design improvements are usually only included to correct obvious deficiencies on the existing highway. Right-of-way acquisition will usually be limited takings, easements and grading rights.*

For NHS and Major Arterial projects, the geometric design criteria for restoration/resurfacing projects on non-freeways are presented in the following sections. On all other projects, the State Standards Highway Design Guide will apply. See the Discussion in Section 11-1.03.

11-4.02 Traffic Volume Controls

The following will apply to restoration/resurfacing projects:

1. Design Year Traffic Volumes. The design year will be 10 years beyond the construction completion date for traffic analyses (AADT, design hourly volume, etc.).

2. Level of Service. Tables 11-8 to 11-11 provide the level-of-service criteria for restoration/resurfacing projects.

3. Traffic Data. The designer should obtain from the Bureau of Planning, Research, and Community Services the traffic data necessary to determine the level of improvement.

4. Capacity Analysis. The analytical techniques in the *Highway Capacity Manual* will be used to conduct the capacity analysis.

11-4.03 Design Speed

In most cases, the existing posted speed limit will be acceptable as the minimum design speed on restoration/resurfacing projects. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

11-4.04 Grades

The existing grades will typically be incorporated into restoration/resurfacing projects.

11-4.05 Crest Vertical Curves

In most cases, existing crest vertical curves will be incorporated into the restoration/resurfacing project. However, the designer should consider reconstruction of a crest vertical curve if:

a. the crest hides from view major hazards such as intersections, sharp horizontal curves or narrow bridges; and

b. the design speed of the existing crest (based on minimum stopping sight distance to an 2' height of object) is more than 20 mph below the project design speed; and

c. the design year AADT is greater than 1500.

11-4.06 Sag Vertical Curves

The existing sag vertical curves will typically be incorporated into restoration/resurfacing projects.

11-4.07 Horizontal Alignment

The existing horizontal alignment will typically be incorporated into restoration/resurfacing projects.

Superelevation Rate/Degree of Curve

To determine the adequacy of the existing curvature and superelevation on a horizontal curve, follow this procedure:

1. Determine the design speed of the existing curve from Figure 11-2.

2. Compare the design speed of the existing curve to the overall design speed for the project (See Section 11-4.03). If the design speed at the curve is less than the project design speed, the designer should evaluate the practicality of increasing the superelevation rate and/or flattening the curve.

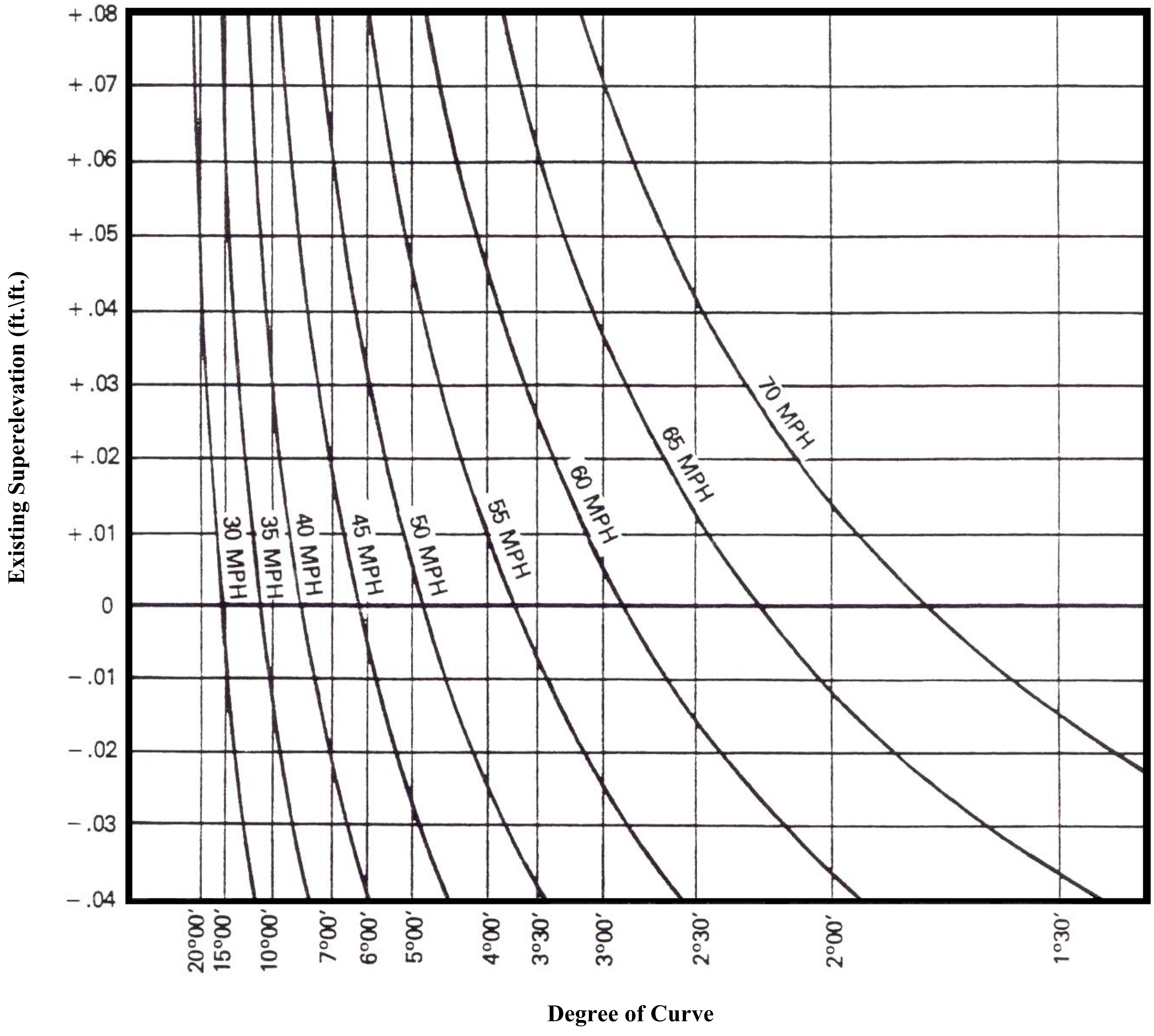
3. If the decision is made to take corrective action, the combination of superelevation and degree of curve will (at a minimum) be based on Figure 11-2.

4. If an existing slope around a curve is less than +1.0%, the designer should consider superelevating the curve at the typical cross slope.

5. Figure 11-2 can also be used to determine the appropriate advisory speed for signing curves that are below the project design speed but will remain in place.

Reverse Curves

For reverse curves on restoration/resurfacing projects, it will be acceptable to provide no tangent section between the curves (i.e., the PT & PC may be coincident).



Note: Figure applies to all rural highways and urban facilities where the design speed is greater than 45 mph

HORIZONTAL CURVATURE FOR RESTORATION/RESURFACING PROJECTS

Figure 11-2

Travelway Widening

The need for widening the travelway on a horizontal curve may be justified even where no changes will be made in the superelevation rate. Section 5-2 presents the applicable criteria.

11-4.08 Cross Section Elements

Tables 11-8 to 11-11 present the Department's restoration/resurfacing criteria for the width of cross section elements. The cross section width and/or steepness of the existing highway should be evaluated against the criteria in the restoration/resurfacing tables. If the existing width or steepness does not meet these criteria, the designer should consider widening the element. If the decision is made to improve the cross section element, the designer should provide a value that at least meets the restoration/resurfacing criteria. However, it may be appropriate to improve the cross section element(s) beyond the restoration/resurfacing criteria.

Right-of-Way

As indicated in the basic definition of a "Restoration/Resurfacing Project," right-of-way acquisition will usually be limited takings, easements and grading rights. Occasionally, more extensive right-of-way involvement may be appropriate if, for example, a horizontal curve is flattened.

Curbs

On restoration/resurfacing projects, the following will apply to the installation or retention of curbs:

1. Type. Where a project will disturb existing curbs, the curb will be replaced in-kind.

2. Height. Restoration/resurfacing projects may include pavement work that will not affect the lateral location of existing curbs, but will affect their reveal. The designer will consider adjusting the reveal of curb (or the pavement design) if:

    a. an analysis of the storm water flow in the gutter indicates overtopping the curb for the design parameters (e.g., design-year frequency, ponding on roadway); and/or

    b. the curb reveal after construction will be less than 3 inches.

Sidewalks

Where a restoration/resurfacing project will disturb existing sidewalks, the sidewalk will be replaced in-kind. Existing sidewalks may also be resurfaced when necessary. Where sidewalks do not currently exist, the need for sidewalks will be determined on a case-by-case basis.

Fill/Cut Slopes

The existing fill and cut slopes will typically be incorporated into the restoration/resurfacing project according to the original design.

Bridges

The Urban and Federal Bridge Program will determine the acceptable roadway width for bridges to remain in place and for new and rehabilitated bridges within the limits of a restoration/resurfacing project. The Urban and Federal Bridge Program will also evaluate the adequacy of existing bridge rails. The designer will be responsible for evaluating the adequacy of the existing guardrail transition approaching the bridge rail.

Transitions

When roadway transitions are required at bridge or underpass sections or at project termini, the length of transition (L) should be computed by the formula $L = WS$ for highways with a design speed greater than 45 mph. The formula $L = WS^2/60$ should be used to compute transitions on highways with a design speed of 45 mph and below. For both formulas, L equals the taper length in feet, W the offset distance in feet, and S the design speed in mph.

11-4.09 Intersections At-Grade

The following summarizes the design of intersections at-grade within the limits of a restoration/resurfacing project.

Intersection Sight Distance (ISD)

The existing ISD will be acceptable.

Turning Radii Design

Normally, the existing radii at an intersection will be acceptable, unless a specific safety or operational problem is identified.

Entrance Design

Section 8-8 and the *MDOT Standard Details* present detailed criteria for entrance design. On restoration/resurfacing projects, the designer should attempt to meet the following objectives:

1. The entrance design should match the roadway work where the existing entrance design is impacted.

2. Where the mainline shoulders are paved and the entrance is gravel, the designer should provide the 3-foot paved apron if not already present. See the entrance figures in Section 8-8 and in the *MDOT Standard Details*.

3. The criteria for handicapped accessibility should be met at entrances.

4. The designer should evaluate safety considerations at driveways (e.g., proximity to intersections) and make any practical improvements.

11-4.10 Roadside Safety

General Application

The Department should take the opportunity of the restoration/resurfacing project to implement practical roadside safety improvements. The designer should review the roadside accident history to assist in the decision-making. The following discussion offers roadside safety criteria that apply specifically to restoration/resurfacing projects.

Roadside Clear Zones

For restoration/resurfacing projects on the NHS and Major Arterials, Table 11-7 presents the recommended clear zone distances. The procedures in Section 10-1 (e.g., clear zones across ditch sections) will apply, except that Table 11-7 will be the basis for the analysis. Tables in the State Standards Highway Design Guide will determine clear zones for all other restoration/resurfacing projects. *The distances given there will be measured from edge of travelway and will include the slope.*

Once a hazard has been identified within the clear zone, the designer should consider the following:

1. Accident Records. The designer should review the accident data to estimate the extent of the roadside safety problem. In particular, there may be sites where clusters of run-off-the-road accidents have occurred (e.g., on the outside of horizontal curves).

2. Location Relative to Clear Zone Distance. The closer an obstacle is to the traveled way, the greater the potential benefits of treatment. It is less likely to be cost effective to treat a hazard near the outer edge of the clear zone boundary.

3. Location Relative to Other Hazards. If a hazard is one of many at about the same distance from the traveled way, this decreases the benefits of treatment. As an example, it may have little benefit to remove an obstacle 12 feet from the travel lane if a line of other obstacles (e.g., trees) are located at 15 feet from the travel lane. However, it may be beneficial to treat an isolated hazard along the roadside that is within the clear zone distance.

4. Treatment Costs. A hazard may be removed, relocated or made breakaway. The costs of these treatments will be a significant factor in the decision-making process.

5. Nature of Hazard. The type of hazard and the available treatments will be a significant factor in the decision-making process. For example, a non-breakaway signpost, which is owned and maintained by the Department, can be made breakaway without any impact on the surrounding environment. However, removing natural features (e.g., trees) may impact the environment and may meet with strong public opposition.

6. Utilities. Utility poles are a common roadside obstacle on restoration/resurfacing projects. Relocation is mandatory when the utility poles physically interfere with construction or when their placement is inconsistent with the Department's "Policy on Above Ground Utility Locations." Relocation for safety benefits must be evaluated on a case-by-case basis.

RESTORATION/RESURFACING PROJECTS

Design Speed (mph)	Design AADT **	Fill Slopes			Cut Section With Ditch Figure 10-1(E) ***
		Recoverable (Figure 10-1(A))		Non-recoverable Figure 10-1(B) ***	
		1:6 or Flatter	1:5 to 1:4		
40 or Less	Under 750 750 - 1500 1500 - 6000 Over 6000	4 5 - 6 6 - 7 7 - 8	4 - 5 6 - 7 7 - 8 8 - 9	SEE PROCEDURE IN SECTION 10-1.03	SEE PROCEDURE IN SECTION 10-1.04
45-50	Under 750 750 - 1500 1500 - 6000 Over 6000	5 - 6 7 - 8 8 - 9 10 - 11	6 - 7 8 - 10 10 - 13 12 - 14*		
55	Under 750 750 - 1500 1500 - 6000 Over 6000	6 - 7 8 - 9 10 - 12 11 - 12	7 - 9 10 - 12 12 - 15* 13 - 16*		
60	Under 750 750 - 1500 1500 - 6000 Over 6000	8 - 9 10 - 12 13 - 15* 15 - 16*	10 - 12 13 - 16* 16 - 20* 18 - 22*		
65-70	Under 750 750 - 1500 1500 - 6000 Over 6000	9 - 10 12 - 13 14 - 16* 15 - 17*	10 - 13* 14 - 18* 17 - 21* 19 - 23*		

* *On non-freeways, the clear zone distance may be limited to 12' for practicality and to provide a consistent roadway template.*

** *Use the AADT projected for the design year for the overall project.*

*** *See the discussion in Section 11-3.10 and Chapter Ten.*

RECOMMENDED CLEAR ZONE DISTANCES
(In Meters Measured From Edge of Travel Lane)

Table 11-7

7. Barrier Protection. The designer should realize that the barrier warrants are based on the relative severity between hazard and guardrail; they do not address the question of whether or not a barrier installation is cost-effective. On restoration/resurfacing projects, the designer must judge whether or not a barrier should be installed when a hazard is within the clear zone and will be left in place.

Roadside clear zones are a controlling design element. For the purpose of determining when a design exception is necessary on a restoration/resurfacing project, the following will apply:

1. Parallel Fill Slopes. The criteria in Table 11-7 or the State Standards Highway Design Guide will determine the applicable clear zone distance. However, where fill slopes are 1:4 or flatter, a maximum distance of 20 feet from the edge of travel lane will apply for design exceptions on rehabilitation projects. On fill slopes steeper than1:4 and where the applicable clear zone extends beyond the toe of the slope, the clear zone distance will be to the toe of the slope for design exceptions. It is desirable to provide a 10 feet clear zone beyond the toe.

2. Horizontal Curves. The horizontal curvature correction in Section 10-1.05 will not apply for the purpose of determining when a design exception is necessary.

Safety Appurtenances

During the design of a restoration/resurfacing project, all existing safety appurtenances should be examined to determine if they meet the latest safety performance and design criteria. This includes guardrail, impact attenuators, median barriers, sign supports, luminaire supports and bridge rail transitions. All safety appurtenances should be upgraded to meet the most recent design criteria. Chapter Ten presents the Department's criteria for the layout and design of safety appurtenances.

Roadside barrier warrants on restoration/resurfacing projects can be especially difficult to resolve. The designer should evaluate the roadside environment against the criteria in Chapter Ten. Basically, the process will be:

1. Determine if barrier is warranted.

2. If an existing run of barrier is located where no barrier is warranted, remove the guardrail.

3. If barrier is warranted, consider removing or relocating the hazard; reducing its severity (e.g., flattening a slope); or making it breakaway.

4. If the hazard cannot be eliminated and a barrier is judged to be cost effective, then install guardrail. The designer should recognize that, depending on the specific site conditions, it may be acceptable to identify a hazard within the applicable clear zone and leave the hazard unshielded. A decision on the cost-effectiveness of barrier installation will be based on construction costs, traffic volumes, accident history, barrier adaptability to the site, etc.

5. For existing runs of guardrail which will remain, ensure that they meet, as practical, the applicable performance and design criteria, including:

   a. operational acceptability (hardware, height, etc.);
   b. dynamic deflection criteria;
   c. length of need;
   d. lateral placement;
   e. placement on slopes and behind curbs; and
   f. end treatments.

Existing and proposed guardrail installations on restoration/resurfacing projects will, in some cases, cause special problems. These include:

1. Guardrail Height. A common problem on restoration/resurfacing projects will be the guardrail height of existing installations because of a pavement overlay. Each existing run that will remain must be considered individually. As a general rule, the designer should seriously consider raising the guardrail when its height, after construction, will be more than 3 inches below the recommended height.

2. Slopes in Front of Barrier. . It will be acceptable to retain existing installations on 1:6 or flatter slopes where the installation is otherwise acceptable. Existing barrier installations may have terminal sections that flare away and terminate on a slope steeper than 1:10, but flatter than or equal to 1:6. If no other barrier deficiencies exist, it will be acceptable to leave the existing installation in place. Where a flared section crosses a ditch section, it may be necessary to place a small pipe and regrade through the ditch to meet this criteria.

3. Length of Need. All existing barrier installations will be evaluated to determine if the existing length of barrier meets the Department's length-of-need criteria in Section 10-4. If the existing length is within 25 feet of the calculated value from Section 10-4, it is not necessary to extend the guardrail.

4. Placement Relative to Shoulder. It is acceptable to place the barrier at the edge of the normal shoulder width where the full 5-foot offset is not attainable. Three feet is the minimum acceptable distance from the face of rail to the shoulder berm.

11-4.11 Tables of Geometric Design Criteria

Tables 11-8 to 11-11 present the criteria for the geometric design of restoration/resurfacing projects on non-freeways. A separate table is presented for the arterial and collector functional classes in urban and rural locations.

11-4.12 Design Exception Process

The discussion in Section 3-7 on exceptions applies equally to the geometric design of restoration/resurfacing projects. The only difference, obviously, is that the designer will be evaluating the proposed design against the criteria presented in Section 11-4.

Design Element				Manual Section **	2 - Lane	Multilane Divided	Multilane Undivided
DESIGN CONTROLS	*Design Speed (2)			3-4	Posted Speed Limit	Posted Speed Limit	
	Access Control			3-5	Entrance Control	Entrance Control	
	Level of Service			3-3	Minimum: D	Minimum: D	
CROSS SECTION ELEMENTS	*Lane Width			6-1	11'	11'	
	*Shoulder Width		Right	6-1	4'	4'	
			Left	6-1	N/A	3'	N/A
	Cross Slope		*Travel Lane	6-1	1.0% to 4.0%	1.0% to 4.0%	
			Shoulder (3)	6-1	4.0%, 2.0% allowable	4.0%, 2.0% allowable	
	Auxiliary Lane Width (4)			6-1	Desirable:11' Minimum: 10'	Desirable:11'	
	Median Width			6-2	N/A	Existing	N/A
	*New and Rehabilitated Bridges		Structural Capacity	~	**SEE BRIDGE PROGRAM**	**SEE BRIDGE PROGRAM**	
			Minimum Width	~			
	*Existing Bridges to Remain in Place		Structural Capacity	~			
			Minimum Width	~			
	Clear Zone			10-1	(5)	(5)	
	Side Slopes (6)	Cut	Front Slope	6-3	Existing	Existing	
			Depth of Ditch	6-3	Existing	Existing	
			Back Slope	6-3	Existing	Existing	
		Fill		6-3	Existing	Existing	
				6-3	Existing	Existing	
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance			4-1	50 mph	55 mph	60 mph
					Existing (7)		
	Passing Sight Distance			4-1	Existing		
	Decision Sight Distance			4-1	N/A		
	*Maximum Degree of Curve			5-2	(8)		
	*Superelevation Rate			5-2	(8)		
	*Horizontal Sight Distance			5-2	Existing		
	*Maximum Profile Grades		Level	4-2	Existing		
			Rolling	4-2	Existing		
			Mountainous	4-2	Existing		
	Minimum Profile Grades			4-2	Desirable: 0.25%	Minimum: 0%	
	*Minimum Vertical Clearance (9)		New and Replaced Overpassing Bridges	4-3	Desirable: 16'-6"	Minimum: 16'-0"	
			Existing Overpassing Bridges	4-3	14'-0"		

* Controlling design criteria (See Section 3-7)

**See Section 11-4 for specific discussion on restoration/resurfacing projects

GEOMETRIC DESIGN CRITERIA FOR RURAL NHS AND MAJOR ARTERIALS
(Restoration/Resurfacing Projects)

Table 11-8

GEOMETRIC DESIGN CRITERIA FOR RURAL NHS AND MAJOR ARTERIALS
(Restoration/Resurfacing Projects)

Footnotes to Table 11-8

1. Multilane Facilities. The criteria in the table for the restoration/resurfacing of multilane facilities will apply to:

   a. an existing multilane facility, or
   b. an existing 2-lane facility which will become one half of a divided highway.

   In the case of "b", the new half of the divided facility will be designed according to the Department's new construction criteria. See Table 7-2.

2. Design Speed. In most cases, the existing posted speed limit will be acceptable as the minimum design speed. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

3. Shoulder Cross Slope. In most cases, the shoulder will be paved. If an existing unpaved shoulder will remain, the shoulder cross slope will be 6.0%. If an existing paved shoulder has a cross slope of 6.0%, it may remain at this rate as part of the restoration/resurfacing project.

4. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 2'.

5. Clear Zone. Clear zones will vary according to design speed, traffic volumes and side slope. See Section 11-4 for clear zones on restoration/resurfacing projects.

6. Side Slopes. In most cases, retention of the existing side slope shape according to the original design will be acceptable.

7. Stopping Sight Distance. The designer should consider reconstruction of a crest vertical curve if:

   a. the crest hides from view major hazards such as intersections, sharp horizontal curves or narrow bridges; and

   b. the design speed of the existing crest (based on minimum SSD to a 2' height of object) is more than 20 mph below the selected design speed for the project; and

   c. the design year AADT is greater than 1500.

8. Maximum Degree of Curve/Superelevation Rate. The combination of degree of curve and superelevation rate will yield a design speed of the existing horizontal curve. See Figure 11-2.

9. Minimum Vertical Clearance. The vertical clearances apply to the arterial passing under. For the 16'-6" clearance, 6" is provided for future resurfacing. The minimum vertical clearance is 17'-6" for the arterial passing under a new sign truss, and 17'-0" for the arterial passing under an existing sign truss. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the arterial.

   Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

   The Urban and Federal Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

	Design Element			Manual Section **	All Traffic Volumes					
DESIGN CONTROLS	*Design Speed (3)			3-4	Posted Speed Limit					
	Access Control			3-5	Entrance Control					
	Level of Service			3-3	Minimum: D					
CROSS SECTION ELEMENTS	*Lane Width			6-1	11'					
	*Shoulder Width/Curb Offset (4)			6-1	4'					
	Cross Slope		*Travel Lane	6-1	1.0% to 4.0%					
			Shoulder	6-1	Paved: 4.0%, 2.0% allowable			Unpaved: 6.0%		
	Auxiliary Lane Width (2)			6-1	Desirable: 11'			Minimum: 10'		
	*New and Rehabilitated Bridges		Structural Capacity	~	SEE BRIDGE PROGRAM			SEE BRIDGE PROGRAM		
			Minimum Width	~						
	*Existing Bridges to Remain in Place		Structural Capacity	~						
			Minimum Width	~						
	Clear Zone			10-1	(3)					
	Side Slopes (4)	Cut	Front Slope	6-3	Existing					
			Depth of Ditch	6-3	Existing					
			Back Slope	6-3	Existing					
		Fill		6-3	Existing					
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance (10)			4-1	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
					Existing (5)					
	Passing Sight Distance			4-1	Existing					
	Decision Sight Distance (11)			4-1	N/A					
	*Maximum Degree of Curve (e = 4.0%)			5-2	(6)					
	*Superelevation Rate			5-2	(6)					
	*Horizontal Sight Distance			5-2	Existing					
	*Maximum Profile Grades		Level	4-2	Existing					
			Rolling	4-2	Existing					
			Mountainous	4-2	Existing					
	Minimum Profile Grades			4-2	Desirable: 0.25%			Minimum: 0%		
	*Minimum Vertical Clearance (7)		New and Replaced Overpassing Bridges	4-3	Desirable: 15'-6"			Minimum: 15'-0"		
			Existing Overpassing Bridges	4-3	14'-0"					

* Controlling design criteria (See Section 3-7)

**See Section 11-4 for specific discussion on restoration/resurfacing projects

GEOMETRIC DESIGN CRITERIA FOR
RURAL NON-NHS MINOR ARTERIAL AND COLLECTOR ROADS
(Restoration/Resurfacing Projects)

Table 11-9

GEOMETRIC DESIGN CRITERIA FOR RURAL NON-NHS MINOR ARTERIAL AND COLLECTOR ROADS
(Restoration/Resurfacing Projects)

Footnotes to Table 11-9

1. Design Speed. In most cases, the existing posted speed limit will be acceptable as the minimum design speed. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

2. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 2'.

3. Clear Zone. Clear zones will vary according to design speed, traffic volumes and side slope. See the State Standards Highway Design Guide for clear zone requirements.

4. Side Slopes. In most cases, retention of the existing side slope shape according to the original design will be acceptable.

5. Stopping Sight Distance. The designer should consider reconstruction of a crest vertical curve if:

   a. the crest hides from view major hazards such as intersections, sharp horizontal curves or narrow bridges; and

   b. the design speed of the existing crest (based on minimum SSD to a 2' height of object) is more than 20 mph below the selected design speed for the project; and

   c. the design year AADT is greater than 1500.

6. Maximum Degree of Curve/Superelevation Rate. The combination of degree of curve and superelevation rate will yield a design speed of the existing horizontal curve. See Figure 11-2.

7. Minimum Vertical Clearance. The vertical clearances apply to the collector passing under. For the 15'-6" clearance, 6" is provided for future resurfacing. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the collector.

   Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

   The Urban and Federal Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

	Design Element		Manual Section **	2-Lane		Multi-lane (Divided/Undivided) (1)	
				With Curb	Without Curb	With Curb	Without Curb
DESIGN CONTROLS	* Design Speed (2)		3-4	Posted Speed Limit		Posted Speed Limit	
	Access Control		3-5	Entrance Control		Entrance Control	
	Level of Service		3-3	Minimum: D		Minimum: D	
	On-Street Parking		6-1	(3)		(3)	
CROSS SECTION ELEMENTS	*Lane Width		6-1	11'		11'	
	*Shoulder Width/Curb Offset	Right	6-1	Existing	4'	Existing	4'
		Left	6-1	N/A		Existing	
	Cross Slope	*Travel Lane	6-1	1.0% to 4.0%		1.0% to 4.0%	
		Shoulder/Curb Offset (6)	6-1	4.0%, 2.0% allowable		4.0%, 2.0% allowable	
	Auxiliary Lane Width		6-1	Existing		Existing	
	CTWLT Lane Width		8-5	Existing		Existing	
	Parking Lane Width		6-1	Existing		Existing	
	Sidewalk Width		6-1	Existing		Existing	
	Median Width		6-2	N/A		Existing	
	*New and Rehabilitated Bridges	Structural Capacity	~	**SEE BRIDGE PROGRAM**		**SEE BRIDGE PROGRAM**	
		Minimum Width	~				
	*Existing Bridges to Remain in Place	Structural Capacity	~				
		Minimum Width	~				
	Clear Zone		10-1	1'	(7)	1'	(7)
	Side Slopes (8)		6-3	Existing		Existing	
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance		4-1	35 mph	40 mph	45 mph	50 mph
				Existing (9)			
	Passing Sight Distance		4-1	Existing			
	Decision Sight Distance		4-1	N/A			
	*Maximum Degree of Curve		5-2	16° 30' (e_{max} = 4.0%)	11° 30' (e_{max} = 4.0%)	See Figure 11-2	
	*Superelevation Rate		5-2	Fig. 5-11 (emax = 4.0%)		See Figure 11-2	
	*Horizontal Sight Distance		5-2	Existing			
	*Maximum Profile Grades	Level	4-2	Existing			
		Rolling	4-2	Existing			
		Mountainous	4-2	Existing			
	Minimum Profile Grades		4-2	Curbed: 0.25% Uncurbed: 0%			
	*Minimum Vertical Clearance (10)	New and Replaced Overpassing Bridges	4-3	Desirable: 16'-6"		Minimum: 16'-0"	
		Existing Overpassing Bridges	4-3	14'-0"			

* Controlling design criteria (See Section 3-7)

**See Section 11-3 for specific discussion on restoration/resurfacing projects

GEOMETRIC DESIGN CRITERIA FOR URBAN NHS AND MAJOR ARTERIAL ROADS/STREETS (Restoration/Resurfacing Projects)

Table 11-10

GEOMETRIC DESIGN CRITERIA FOR URBAN NHS AND MAJOR ARTERIAL ROADS/STREETS (Restoration/Resurfacing Projects)

Footnotes to Table 11-10

1. Multilane Facilities. The criteria in the table for the restoration/resurfacing of multilane facilities will apply to:

   a. an existing multilane facility, or
   b. an existing 2-lane facility which will become one half of a divided highway.

   In the case of "b", the new half of the divided facility will be designed according to the Department's new construction criteria. See Table 7-5.

2. Design Speed. In most cases, the existing posted speed limit will be acceptable as the minimum design speed. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

3. On-Street Parking. Typically, a restoration/resurfacing project will neither introduce nor remove on-street parking.

4. Lane Width. In restricted built-up areas (e.g., CBD), a 10' lane width is acceptable.

5. Shoulder Width. On non Federal-aid projects, the existing shoulder width may be retained.

6. Cross Slope (Curb Offset). For curb offsets (shoulder width less than 4'), the cross slope will be the same as the cross slope of the adjacent travel lane.

7. Clear Zone. Clear zones will vary according to design speed, traffic volumes and side slope. See Section 11-4 for clear zones on restoration/resurfacing projects.

8. Side Slopes. In most cases, retention of the existing side slope shape according to the original design will be acceptable.

9. Stopping Sight Distance. The designer should consider reconstruction of a crest vertical curve if:

   a. the crest hides from view major hazards such as intersections, sharp horizontal curves or narrow bridges; and

   b. the design speed of the existing crest (based on minimum SSD to a 2' height of object) is more than 20 mph below the selected design speed for the project; and

   c. the design year AADT is greater than 1500.

10. Minimum Vertical Clearance. The vertical clearances apply to the arterial passing under. For the 16'-6" clearance, 6" is provided for future resurfacing. The minimum vertical clearance is 17'-6"for the arterial passing under a new sign truss, and 17'-0" for the arterial passing under an existing sign truss. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the arterial.

    Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

    The Urban and Federal Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

Design Element			Manual Section **	With Curb	Without Curb
DESIGN CONTROLS	* Design Speed (1)		3-4	Posted Speed Limit	
	Access Control		3-5	Entrance Control	
	Level of Service		3-3	Minimum: D	
	On-Street Parking		6-1	(2)	
CROSS SECTION ELEMENTS	*Lane Width		6-1	Minimum: 11'	
	*Shoulder Width		6-1	Existing	Minimum: 4' (3)
	Cross Slope	*Travel Lane	6-1	1.0% to 4.0%	1.0% to 4.0%
		Shoulder (4)	6-1	4.0%, 2.0% allowable	
	Auxiliary Lane Width		6-1	Existing	
	Parking Lane Width		6-1	Existing	
	Sidewalk Width		6-1	Existing	
	*New and Rehabilitated Bridges	Structural Capacity	~	**SEE BRIDGE PROGRAM**	**SEE BRIDGE PROGRAM**
		Minimum Width	~		
	*Existing Bridges to Remain in Place	Structural Capacity	~		
		Minimum Width	~		
	Clear Zone		10-1	Minimum: 1'	(5)
	Side Slopes (6)		6-3	Existing	
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance		4-1	25 mph / 30 mph	35 mph / 40 mph
				Existing (7)	
	Passing Sight Distance		4-1	Existing	
	Decision Sight Distance		4-1	N/A	
	*Maximum Degree of Curve (e = 4.0%)		5-2	Figure 5-12	Existing
	*Superelevation Rate		5-2	Figure 5-12	Existing
	*Horizontal Sight Distance		5-2	Existing	
	*Maximum Profile Grades	Level	4-2	Existing	
		Rolling	4-2	Existing	
		Mountainous	4-2	Existing	
	Minimum Profile Grades		4-2	0.25%	0%
	*Minimum Vertical Clearance (8)	New and Replaced Overpassing Bridges	4-3	Desirable: 15'-6"	Minimum: 15'-0"
		Existing Overpassing Bridges	4-3	14'-0"	

* Controlling design criteria (See Section 3-7)

**See Section 11-4 for specific discussion on restoration/rehabilitation projects

GEOMETRIC DESIGN CRITERIA FOR
URBAN NON-NHS MINOR ARTERIAL AND COLLECTOR ROADS/STREETS
(Restoration/Resurfacing Projects)

Table 11-11

GEOMETRIC DESIGN CRITERIA FOR URBAN NON-NHS MINOR ARTERIAL AND COLLECTOR ROADS/STREETS (Restoration/Resurfacing Projects)

Footnotes to Table 11-11

1. Design Speed. In most cases, the existing posted speed limit will be acceptable as the minimum design speed. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

2. On-Street Parking. Typically, a restoration/resurfacing project will neither introduce nor remove on-street parking.

3. Shoulder Width. On non Federal-aid projects, the existing shoulder width may be retained.

4. Cross Slope (Curb Offset). For curb offsets (shoulder width less than 4'), the cross slope will be the same as the cross slope of the adjacent travel lane.

5. Clear Zone. Clear zones will vary according to design speed, traffic volumes and side slope. See the State Standards Highway Design Guide for clear zone requirements.

6. Side Slopes. In most cases, retention of the existing side slope shape according to the original design will be acceptable.

7. Stopping Sight Distance. The designer should consider reconstruction of a crest vertical curve if:

   a. the crest hides from view major hazards such as intersections, sharp horizontal curves or narrow bridges; and

   b. the design speed of the existing crest (based on minimum SSD to a 2' height of object) is more than 20 mph below the selected design speed for the project; and

   c. the design year AADT is greater than 1500.

8. Minimum Vertical Clearance. The vertical clearances apply to the collector passing under. For the 15'-6" clearance, 6" is provided for future resurfacing. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the collector.

   Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

   The Urban and Federal Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

11-5 4R FREEWAY PROJECTS

11-5.01 Definition

Section 3-6 defines 4R freeway projects as follows:

> *4R projects (resurfacing, restoration, rehabilitation and/or reconstruction) on existing freeways are primarily intended to extend the service life of the existing facility, to enhance highway safety and to make improvements to the existing geometrics, where practical.*

If the nature of the work on an existing freeway is considered reconstruction, the criteria in Table 7-1 for new construction/reconstruction projects will apply, and the criteria in Chapters Three to Ten will apply. If the nature of the work is considered rehabilitation, restoration or resurfacing, the criteria in Section 11-5 will apply.

11-5.02 4R Project Objectives

As with non-freeway 3R projects, it is often impractical to fully apply new construction criteria to 4R freeway projects without some qualifications. Therefore, the objective of a 4R project is, within practical limits, to return the freeway to its original level of serviceability or to improve its serviceability to meet current and future demands. This objective applies to all aspects of the freeway's serviceability, including:

1. structural adequacy,
2. drainage,
3. level of service for the traffic flow,
4. geometric design,
5. roadside safety, and
6. traffic control.

11-5.03 Application

4R freeway projects are most often initiated to make a specific improvement to the freeway. Therefore, the Department’s approach to the geometric design of 4R freeway projects is to selectively evaluate and improve the existing geometrics. Table 11-12 presents the Department's geometric design criteria for 4R projects. The 4R approach is summarized as follows:

1. Nature of Improvement. This may include:

   a. pavement resurfacing, restoration, rehabilitation or reconstruction, including shoulders;

   b. adding through travel lanes to improve the level of service;

   c. improving roadway delineation;

   d. upgrading roadside safety (always required);

   e. increasing the length of acceleration or deceleration lanes at an interchange;

   f. widening an existing bridge as part of a bridge rehabilitation project; and/or

   g. improving the roadside drainage.

   The designer will exercise judgment when determining any other improvements that may be practical.

2. Exceptions. The discussion in Section 3-7 on design exceptions will only apply to the geometric design of the specific freeway improvement(s).

11-5.04 Traffic Volume Controls

The following will apply to 4R freeway projects:

1. Design Year Traffic Volumes. The design year will be 20 years beyond the construction completion date for traffic analyses (AADT, design hourly volume, etc.).

2. Level of Service. The desirable level of service is B; the minimum level of service in rural areas is C and in urban areas is D.

3. Traffic Data. The designer should obtain from the Bureau of Planning the traffic data necessary to determine the level of improvement.

4. Capacity Analysis. The analytical techniques in the *Highway Capacity Manual* will be used to conduct the capacity analysis.

11-5.05 Design Speed

In most cases, the existing posted speed limit will be acceptable as the minimum design speed for the 4R freeway project. However, the designer should check with the Traffic Engineering Division to determine if the existing posted speed limit is likely to change after project completion.

11-5.06 Horizontal/Vertical Alignment

Unless the specific objective of the 4R freeway project is to improve one or more horizontal/vertical features, the existing alignment will be acceptable. The Urban and Federal Bridge Program is responsible for determining the adequacy of existing or proposed vertical clearances.

11-5.07 Bridges

The Urban and Federal Bridge Program will determine the acceptable width for bridges to remain in place and for new and rehabilitated bridges within the limits of a 4R project. The Urban and Federal Bridge Program will also evaluate the adequacy of existing bridge rails. The designer will be responsible for evaluating the adequacy of the existing guardrail transition at the bridge rail.

11-5.08 Interchanges

A 4R freeway project may include proposed work on a freeway interchange. The work may be to rehabilitate the entire interchange or to make only selective improvements to the interchange geometrics. The designer will apply Chapter Nine to the design of the interchange elements.

11.5.09 Roadside Safety

All 4R freeway projects will be evaluated for potential roadside safety improvements within the project limits. The criteria in Chapter Ten will fully apply to the evaluation. This includes roadside clear zones, barrier warrants, barrier design and drainage features.

Existing intersecting slopes in the median will be evaluated for potential improvements. In general, existing median slopes may be retained in the absence of an adverse accident history. If the existing median slope is flattened, it should be reconstructed to a 1:10 (desirable) or a 1:6 slope (acceptable).

11-5.10 Table of Geometric Design Criteria

Table 11-12 presents the Department's criteria for the geometric design of 4R freeway projects.

Design Element			Manual Section **	Rural	Urban
DESIGN CONTROLS		* Design Speed (1)	3-4	Posted Speed Limit	Posted Speed Limit
		Access Control	3-5	Controlled Access	Controlled Access
		Level of Service	3-3	Desirable: B Minimum: D	Desirable: B Minimum: D
CROSS SECTION ELEMENTS	*Lane Width		6-1	12'	12'
	*Shoulder Width	Right	6-1	10'	10'
		Left	6-1	4'	4'
	Cross Slope	*Travel Lane	6-1	1.5% to 2.0%	1.5% to 2.0%
		Shoulder (4)	6-1	4.0% to 6.0%	4.0% to 6.0%
	Auxiliary Lane Width (3)		6-1	12'	12'
	Median Width (4)		6-21	Existing	Existing
	*New and Rehabilitated Bridges	Structural Capacity	~	**SEE BRIDGE PROGRAM**	**SEE BRIDGE PROGRAM**
		Minimum Width	~		
	*Existing Bridges to Remain in Place	Structural Capacity	~		
		Minimum Width	~		
	Clear Zone		10-1	(5)	(5)
	Side Slopes (6)	Cut: Front Slope	6-3	Existing	Existing
		Cut: Depth of Ditch	6-3	Existing	Existing
		Cut: Back Slope	6-3	Existing	Existing
		Fill	6-3	Existing	Existing
ALIGNMENT ELEMENTS	*Minimum Stopping Sight Distance		4-1	55 mph / 60 mph	65 mph / 70 mph
				Existing	
	Decision Sight Distance		4-1	Existing	
	*Maximum Degree of Curve		5-2	Existing	
	*Superelevation Rate		5-2	Existing (7)	
	*Horizontal Sight Distance		5-2	Existing	
	*Maximum Profile Grades	Level	4-2	Existing	
		Rolling	4-2	Existing	
		Mountainous	4-2	Existing	
	Minimum Profile Grades		4-2	Desirable: 0.25% Minimum: 0%	
	*Minimum Vertical Clearance (8)	New and Replaced Overpassing	4-3	16'-6"	
		Existing Overpassing	4-3	16'-0"	

* Controlling design criteria (See Section 3-7) **See Section 11-5 for specific discussion on 4R projects

***Table 11-15 applies to freeway projects considered rehabilitation, restoration or resurfacing. For freeway reconstruction projects, see Table 7-1.

GEOMETRIC DESIGN CRITERIA FOR FREEWAYS***
(4R Projects)

Table 11-12

GEOMETRIC DESIGN CRITERIA FOR FREEWAYS
(4R Projects)

Footnotes to Table 11-12

1. Design Speed. In most cases, the existing posted speed limit will be acceptable as the minimum design speed. However, the designer should check with the Traffic Engineering Division to determine if the existing posted speed limit is likely to change after project completion.

2. Shoulder Width. Where a concrete median barrier is used, the desirable left shoulder is 6' for freeways with two lanes in one direction. For all freeways with three or more lanes in one direction, the desirable left shoulder is 10'.

3. Auxiliary Lane Shoulders. Shoulder widths adjacent to auxiliary lanes should be 8'.

4. Median Width. It is acceptable to reduce the existing median width where travel lanes are added in the median.

5. Clear Zone. Clear zones will vary according to design speed, traffic volume and side slope. See Section 10-1.

6. Side Slopes. In most cases, retention of the existing side slope shape according to the original design will be acceptable.

7. Superelevation Rate. Normally, the existing superelevation rate will be adequate. However, the designer should refer to Table 5-6 to determine if any improvements should be considered.

8. Minimum Vertical Clearance. The vertical clearances apply to the freeway passing under. For the 16'-6" sign truss clearance, 6" is provided for future resurfacing. The minimum vertical clearance is 17'-6" for the freeway passing under a new pedestrian bridge or new. The clearance is 17'-0" for the freeway passing under an existing pedestrian bridge or existing sign truss. A 22'-6" (±6") clearance, depending on actual site conditions, is required at railroad underpasses beneath the freeway.

   Note that "existing overpassing bridges" refers to any bridge work which does not require the total replacement of both the substructure and superstructure. For example, a bridge deck rehabilitation would be considered an existing overpassing bridge for the purpose of determining the minimum vertical clearance.

   The Urban and Federal Bridge Program will make the final determination on the adequacy of existing or proposed vertical clearances.

11-6 SPOT IMPROVEMENT PROJECTS (Non-Freeways)

11-6.01 Definition

Section 3-6 defines spot improvements as follows:

> *Spot improvements are intended to correct an identified deficiency at an isolated location. The deficiency may be related to structural, geometric, safety, and drainage or traffic control problems. These projects are not intended to provide a general upgrading of the highway, as are projects categorized as new construction, reconstruction, 3R or 4R.*

One example of a spot improvement is a safety project at a site with a disproportionate number of accidents. These projects are intended to provide cost-effective countermeasures to reduce the accident potential. Typical projects are intersection improvements, flattening a horizontal curve, installing guardrail or installing traffic control devices. The Traffic Engineering Division is responsible for conducting a preliminary evaluation of the site and recommending improvements. When roadway work is involved, the Urban and Arterial Highway Program is responsible for preparing the detailed project design.

11-6.02 Application

The Department has adopted a flexible approach to the geometric design of spot improvement projects. The following summarizes the approach:

1. Numerical Criteria. The designer should consider the level of improvement that will most likely be used to upgrade the highway section in the future as well as the roadway classification. Refer to the discussion in Section 11-1.03. Spot improvements should be made with the applicable criteria in mind.

2. Design Speed. The existing posted speed limit will usually be acceptable as the minimum design speed. However, the designer should check with Traffic Engineering to determine if the existing posted speed limit is likely to change after project completion.

3. Application. The designer should apply the selected criteria specifically to the geometric improvement related to the objective of the spot improvement project (e.g., install guardrail, flatten a curve, add a left-turn lane). In addition, the designer should evaluate other geometric design deficiencies within the project limits. The designer should consider improving any severe deficiencies, even if not related to the specific objective of the spot

improvement. The designer will exercise his/her judgment when determining any other improvements that may be justified.

4. Exceptions. For spot improvements, the exception process will apply to those specific elements that are improved by the project. See Section 3-7 for a discussion on the design exception process.

CHAPTER TWELVE

DRAINAGE DESIGN

STATE OF MAINE

URBAN & ARTERIAL

HIGHWAY DESIGN GUIDE

January 2005

Chapter Twelve

DRAINAGE DESIGN

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

Chapter Twelve
DRAINAGE DESIGN

12-1 *GENERAL DRAINAGE POLICY DIRECTIVES*

12-1.01 Introduction

This chapter will provide the drainage policies, criteria and references approved for use by the Maine Department of Transportation (MDOT). The objective is to provide the basic information needed by the highway designer, hydrologist, and/or hydraulic engineer to perform the hydrological and hydraulic analyses for which he/she is responsible. A list of references has been provided at then end of this chapter which provide more details about the methods and theory recommended in this chapter. This Guidance Document has been prepared by the Hydrology Section of the Environmental Office with assistance from other Maine DOT Staff.

In using this Manual, it should be understood that the intent is to provide guidelines dealing with situations commonly encountered in design. It is hoped that in most situations, the methods may be applied directly, in a straight-forward manner. That said, this Manual should not be seen as a "cookbook", as it cannot possibly anticipate every possible design issue. All design presumes professional judgment and experience on the part of the designer, informed by these guidelines and policies. Departures from these guidelines should be noted and documented by the person in responsible charge of the project design. Deviations from policy should be approved by appropriate MDOT staff.

Users of this manual are encouraged to share comments and suggestions for improvement with the Hydrology Section. Please direct all communication to

Maine Department of Transportation
Environmental Office - Hydrology Section
16 State House Station
Augusta, ME 04333-0016
Phone: 207-624-3100
Fax: 207-624-3101
Web address: http://www.state.me.us/mdot/env/homepage.html

12-1.02 Department Responsibility

The Urban/Arterial and Bridge Programs are both responsible for drainage analyses for projects under the jurisdiction of the Department. The Regional Program and Division offices will also have occasion to employ the drainage analysis and design methods described in this chapter.

Responsibility for different kinds of drainage systems is generally assigned as follows:

1) Closed Drainage Systems: Urban/Arterial Program
2) Bridges and Box Culverts: Bridge Program
3) Other Culverts: Bridge, spans $\geq$ 10 ft; Urban/Arterial or Regional, spans < 10 ft
4) Open Channels: responsibility is project-specific

12-1.03 Coordination with Other Agencies and DOT Offices

Modification to any drainage system can affect areas away from the area of construction. The analyst should be aware of future land-use plans and any expected changes to water courses, and should also investigate all future Federal, State, and local agency plans which may affect drainage.

Storm Water Memorandum of Agreement

The Maine Department of Environmental Protection (DEP) regulates storm water impacts due to site development. A Memorandum of Agreement (MOA) between DEP, MDOT, and the Maine Turnpike Authority (MTA) was signed in 1998 in order to streamline compliance by MDOT with state storm water quantity and quality regulations. Storm water quality issues are focused primarily on prevention and control of sedimentation and erosion; quantity issues are focused on controlling increases in peak flow from project sites. The Water Resources Section of the MDOT Environmental Office is responsible for water quality issues on MDOT projects; the Hydrology Section is responsible for storm water quantity.

The Storm Water Quantity Standard in the MOA states that

MDOT and MTA will calculate the peak flow from the site of a project if the project: 1) combines two or more sub drainage areas, and 2) includes 20,000 sq. ft. or more of new impervious area or five acres or more of disturbed are in the direct watershed of a waterbody most at risk from new development (as defined in DEP's Chapter 500 and 502), or one acre or more of new impervious area or five acres or more of disturbed area elsewhere. MDOT and MTA will design project ditches, culverts, and outlet areas to be stable and will minimize any increase in peak flow from the project site. In those instances in which a peak flow increase will result, MDOT and MTA shall take engineering measures to avoid adverse impacts to offsite property as a result of drainage increases resulting from the project.

12-1.04 Information Required

Data typically developed as part of a drainage study will include, but is not limited to, watershed delineations, areas, slopes, flowpaths, times of concentrations, Rational Method runoff coefficients, and SCS Runoff Curve Numbers. In most cases, design flows will be calculated as part of the watershed characterization effort; flow computation will not ordinarily be separated from watershed characterization.

Information included in a drainage report will generally consist of

1) a brief description of the drainage basin under analysis
2) a brief description of how the data was obtained
3) a map(s) of the drainage area which provides pertinent information
4) a completed Drainage Study form (MS-Excel worksheet) containing pertinent watershed characteristics and computed design flows.

When at all feasible, drainage study documents should be prepared in digital format (spreadsheets, word processing documents, CAD files, scanned images). Current Department policy is to minimize the retention of paper "hard copy". All standard drainage reports and calculations should be executed using MS-Excel spreadsheet templates prepared specifically for this purpose by the Hydrology Unit.

12-1.05 Documentation Procedures

The following items should be included in the project file. The intent is not to limit the data to only those items listed, but rather to establish a minimum requirement consistent with the hydraulic design procedures outlined in this Guide. Any additional information essential to the hydraulic design should also be included.

Report Documentation

A summary report should be prepared for every drainage study. The recommended report format is discussed later in this chapter. The remainder of this section describes the kind of information that may be generated in the process of a study. This information will be summarized and presented in the report. This information may also be preserved in working documents such as spreadsheets, maps, photos, etc. To the greatest extent possible, information should be converted to digital form for final project archiving.

General Comment on Computer Files

It is anticipated that most information will be summarized and used in the form of computer files. All final, and other important, worksheets and computer program input/output files should be saved to the project directory. An index (as a MS-Word or MS-Excel file) of all drainage study computer files should be prepared, with a brief description of each file. Important paper documents that are not computer-originated (e.g., photos, USGS topographic

maps) should be scanned for archival with project drainage study computer files. Files created with software should be archived in native format (e.g., as MS-Word or MS-Excel files that can subsequently be changed) as well as "printed" to Adobe [.PDF] files corresponding to final results for design in the interests of preserving file integrity.

Hydrology

Drainage studies should be documented according to the guidance in Section 12-2.10, "Documentation of Hydrologic Studies".

Culverts

The following items should be included in the project file, when applicable:

1) culvert performance curves
2) allowable headwater elevation and basis for selection
3) tailwater elevation and basis of selection
4) cross-section(s) used in the design of highwater determinations
5) roughness coefficient assignments ("n" values)
6) observed highwater, dates, and estimated discharges
7) stage discharge curve for undisturbed, existing and proposed conditions to include the depth and velocity measurements or estimates and locations for the design, 50-year and check floods
8) performance curves showing the calculated backwater elevations, outlet velocities and scour for the design, 50-year and any historical floods
9) type of culvert entrance condition
10) culvert outlet appurtenances and energy dissipation calculations and designs
11) roadway geometry (plan and profile)
12) potential flood hazard to adjacent properties

Closed Systems (Stormwater Drainage Systems)

The following items should be included in the project file or project computer directory:

1) computations for inlets and pipes
2) drainage area map
3) design frequency
4) documentation of outfalls, existing storm drains, and other design considerations
5) a schematic indicating closed system layout

Open Channels

The following items should be included in the project file (if applicable):

1) stage-discharge curves for the design, 50-year, 100-year and any historical events
2) cross-section(s) used in the design water surface determinations and their locations

3) roughness coefficient assignments ("n" values)
4) information on the method used for design water surface determinations
5) observed highwater, dates, and discharges
6) channel velocity measurements or estimates and locations
7) design or analysis of materials proposed for the channel bed and banksenergy dissipation calculations and designs
8) copies of all computer analyses

12-1.06 **Design Event Frequency**: **Selection of Peak Discharge**

General policy is to design open drainage systems for the 50-year event and closed drainage (storm sewer) systems for the 10-year event. Roadway cross-culverts and open channels should also be checked for performance under the 100-year event; driveway culverts should be designed for the 10-year event. Rational method and rainfall-runoff models use storms of the specified frequency. Storm duration is assigned according to watershed time of concentration t_c, with a minimum value of t_c = 5 minutes. This policy is summarized in Table 12-1.1.

Table 12-1.1: RECOMMENDED DESIGN FLOOD FREQUENCY

Highway Functional Class	Drainage Structure			
	Roadway Cross Culvert[1]	Driveway Culvert[2]	Closed System[3]	Open Channel[1]
Freeway	50-year	N/A	10-year	50-year
Other Arterials	50-year	10-year	10-year	50-year
Collectors & Locals	50-year	10-year	10-year	50-year

[1] *Impacts of the 100-year event should also be checked.*
[2] *If driveway culvert is part of main system, design for the 50-year event.*
[3] *Storm duration = catchment time of concentration, with 5 minute minimum duration.*

Exceptions to Recommended Design Frequency

Some roads may warrant design to a higher flood frequency, e.g., 100 years. These roads include major arterials that offer few or no detour options and roads that serve significant health, safety and other public facilities. The exceptions should be identified on a case-by-case basis in consultation with Division personnel and local officials.

Occasionally, some roads may warrant design to a lower risk, primarily in cases where design to the recommended frequency is too expensive. Such exceptions should be clearly identified and fully documented.

Ditches

Roadside ditches are not designed for a particular frequency, as they are usually not a limiting factor in system capacity. Based on the designer's experience and the requirements of a specific

project, ditches may be sized to a specific frequency following the above table. More often, ditches are placed to a standard depth to allow subbase drainage. In some cases, ditches cannot be placed to standard depth because it would require excessive backslope, thus impacting the adjacent property owner. A combination of shallow ditch and underdrain may be used to convey storm water and drain the subbase. In these situations, the shallow ditch capacity should be checked against the design flow.

Storm and Flood Frequencies

Unless otherwise stated, it is assumed that a flow of a particular frequency is produced by a rainfall event of the same frequency. While there are regular situations in Maine where this is not justified, the complexity of the underlying physical hydrology and climatic conditions as well as limited resources require this simplifying assumption. These other situations may be addressed on a project-specific basis where appropriate (e.g., based on past flooding experience, maintenance experience, designer concerns) and where the necessary data are available.

12-1.07 Execution of Work

Drainage analysis may be performed in-house by MDOT staff or by outside consultants, according to the particular needs of the MDOT. MDOT Drainage Policy shall be followed in either case. This manual is intended to document MDOT Drainage Policy as well as provide technical guidance for implementing that policy. However, this technical guidance is not intended to supercede the professional judgement of the licensed Professional Engineer in overall responsible charge of a drainage study.

12-1.08 Units of Measurement, Specification, and Analysis

MDOT policy is that design is performed in U.S. Customary units whenever possible and sensible, and that all designs are presented in U.S. Customary units exclusively. Most equations are given here in a general form valid for both Customary and metric units; appropriate conversion factors are also supplied. Even in Customary form, some equations may be cast in inconsistent units (e.g., ft^3/s, ac, and in/hr in the Rational formula). Preferred units for hydrologic and hydraulic reporting are given in Table 12-1.2. Common conversion factors are given Table 12-1.3. All tables and figures in the body of this chapter are given in U.S. Customary units; the same tables are given in metric in the appendix.

Table 12-1.2: Preferred Units for Hydrologic and Hydraulic Analysis and Design

Quantity	Symbol	U.S. Customary	Metric
Length	L	ft or mi	m or km
Area	A	ac, ft^2, or mi^2	ha, m^2, or km^2
Flow Rate	Q	ft^3/s	m^3/s
Velocity	v	ft/s	m/s
Rainfall Intensity	i	in/hr	mm/hr
Storm Depth	d	In	mm
Pipe Diameter	D	in or ft	mm or m
Time of Concentration	t_c	min	min
Slope	S	ft/ft or ft/mile	m/m or m/km

12-1.09 Vertical Datum

The Maine Department of Transportation, Survey Section, completed its conversion to the 1988 North American Vertical Datum (NAVD) in 1999. Since January, 2000, all new projects, with a few exceptions, are in the NAVD 1988 datum. If there is any doubt about what vertical datum was used for a project, the datum should be confirmed before proceeding.

Most existing MDOT plans, historical flood information, and U.S. Geological Survey topographical maps are based on the 1929 National Geodetic Vertical Datum (NGVD). Elevations *Z* based on the older NGVD 1929 need to be converted to the newer NAVD 1988 using the following equation:

$$Z_{NGVD} - Z_{shift} = Z_{NAVD}$$

The datum shift (correction factor) Z_{shift} ranges between 0.591 ft (0.18 m) and 0.722 ft (0.22 m). The exact datum shift for a specific location in Maine can be calculated using the *VERTCON* program at the following National Geodetic Survey (NGS) Internet website:

http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl

The following data is required as input on the web page:

1) North Latitude (Required)
2) West Longitude (Required)
3) Orthometric Height (Optional)

Latitude and Longitude may be entered in any of the following three formats:

1) degrees, minutes and decimal seconds (ddd mm ss.sss)
2) degrees and decimal minutes (ddd mm.mmm)
3) decimal degrees (ddd.ddddd)

There must be one or more blanks between entry fields. Decimals can be keyed commensurate with the field's precision, but are not required.

Example Problem: Presque Isle, Gouldville Bridge #3881

Q_{100} Elevation = 431 ft (131.37 m) from Flood Insurance Study based on NGVD 1929. Determine the NAVD flood elevation.

Step 1.) Go to website and get datum shift by entering latitude and longitude for the location you are interested in.

Latitude 46.667°
Longitude 68.00°
Datum shift = 0.627 ft (0.191 m)

Step 2.) Subtract datum shift from elevation based on NGVD 1929 to convert to NAVD 1988.

$$Z_{\text{NGVD}} - Z_{\text{shift}} = Z_{\text{NAVD}}$$

$$431 \text{ ft} - 0.627 \text{ ft} = 430.373 \text{ ft}$$

All hydrology/hydraulics reports should state what vertical datum is used. For example, the following statement can be added at the end of the hydraulics report:

Note: *All elevations based on North American Vertical Datum (NAVD) 1988. Elevations based on the National Geodetic Vertical Datum (NGVD) 1929 were converted to NAVD by the appropriate shift (0.627 ft) using NGS Vertcon program.*

Table 12-2.3: Common Conversion Factors

Length	1 in	=	25.4 mm
	1 m	=	3.28 ft
	1 mi	=	5,280 ft
	1 mi	=	1.61 km
	1 m	=	10^2 cm
	1 m	=	10^3 mm
	1 km	=	10^3 m
Area	1 ac	=	43,560 ft^2
	1 mi^2	=	640 ac
	1 mi^2	=	2.59 km^2
	1 km^2	=	247 ac
	1 hectare	=	2.47 ac
	1 hectare	=	10^4 m^2
	1 km^2	=	10^6 m^2
	1 km^2	=	10^2 hectare
Volume	1 m^3	=	35.29 ft^3
	1 ft^3	=	7.48 gal
	1 ac-ft	=	43,560 ft^3
	1 gal	=	3.785 liters
Time	1 day	=	86,400 sec
	1 day	=	1,440 min
	1 hr	=	3,600 sec
Pressure	1 atm	=	10.35 m H_2O
	1 atm	=	101.4 kiloPascals (kPa)
	1 atm	=	14.7 lbs/in^2

Density of Water $\rho_w = 1\ g/cm^3 = 10^3\ kg/m^3 = 62.4\ lb/ft^3$

Gravity $g = 9.81\ m/s^2 = 32.2\ ft/s^2$

12-2 *HYDROLOGY*

12-2.01 Introduction

The hydrologic analysis will determine the peak discharge for the selected design frequency and site conditions. This discharge will be used in determining the required size of highway facilities in the hydraulic analysis. On occasion, complete flood hydrographs for storage routing may also be determined to support design of detention ponds and size culverts.

12-2.02 Methods of Estimating Peak Discharge

The Maine Department of Transportation (MDOT) uses several methods of estimating design event peak flow rates, volumes, and timing. Experience has shown these methods to be practical, economical, and within the limits of attainable accuracy. The following methods are regularly employed in MDOT practice:

1. Rational Method
2. U.S. Geological Survey (USGS Hodgkins) Regression Equations
3. Rainfall-Runoff Hydrograph Modeling (including, but not limited to, TR-20)
4. Published Flow Records
5. Flood Reports

Additional sources of valuable information are

1. Documented testimony
2. Maintenance experience
3. Local anecdotal experience
4. High water marks and observations
5. River/stream geomorphologic observations

More complex hydrology and hydraulic computer simulation models might be applied in project-specific cases. However, these methods typically require costly field data, large amounts of data preparation, model setup and calibration, and interpretation, not to mention staff expertise to execute these tasks. Therefore, such methods can only be justified in unusual or sensitive situations.

In the discussion that follows, TR-20 is identified explicitly in view of its widespread use in the Maine engineering community. However, its use in this manual should be understood as a surrogate for all rainfall-runoff modeling approaches.

12-2.03 Selecting a Flood Estimation Procedude

The choice of an estimation method is driven by the specific technical needs of a project subject to the usual requirements of watershed characteristics, accuracy and cost-efficiency. In many highway design applications, just the peak instantaneous flows are needed and the Rational Method and USGS Regression Equations will be the methods of choice. Even when other methods are employed (typically, event rainfall-runoff modeling as in TR-20), Rational and USGS should be used to check the reasonableness of model results. In all cases, the analyst should consult with maintenance staff, local authorities, and local residents for their experience with flooding at the site under study. Table 12-2.1 outlines the appropriate choice of method for particular situations when only the peak instantaneous flow is needed.

Table 12-2.1: Methods[1] for Peak Flow Calculation for Culverts & Ditches

Watershed Area	Rural	Urban
< 0.5 mi^2 (320 ac = 1.25 km^2)	Rational and Modeling	Rational and Urban USGS[3]
0.5 – 1 mi^2 (320 ac - 640 ac or 1.3 km^2 – 2.6 km^2)	Rational, USGS[2,5] and Modeling[4]	Rational, Urban USGS and Modeling
> 1 mi^2 (640 ac = 2.6 km^2)	USGS	Urban USGS

Notes:
1) At the discretion of MDOT, other methods may be used on a project-specific basis
2) USGS indicates USGS (Hodgkins, 1999) regression equations (Water-Resources Investigations Report 99-4008, USGS, Augusta, ME, 1999)
3) Urban USGS indicates regression equations with Sauer correction for urbanization as documented in Hodgkins (1999)
4) Modeling will generally be performed with TR-20 or equivalent. MDOT may approve alternative models on a project-specific basis. See further comments on use of modeling.
5) USGS is only a secondary method for small watersheds (< 1 mi^2)

Rational and USGS Regression are the simplest methods to apply. TR-20 event modeling is moderately more data intensive. Even though TR-20 gives the appearance of being a physically based, detailed representation of hydrologic processes, its performance in comparable situations is no better (and often worse) than Regression and Rational. In contemporary Maine practice, event modeling is often performed with *HydroCad* (Applied Microcomputer Systems, Inc., 2001), an easy-to-use proprietary derivative of TR-20 methodology, as well as other models with highly developed user interfaces. While internal MDOT practice is to use Rational Method on small watersheds, event models will also be accepted.

<u>USGS Regression</u>

USGS Regression offers several advantages over other methods:

1) is only method with established accuracy limits
2) is at least as accurate as the other methods
3) is demonstrably more accurate than rainfall-runoff modeling in comparable situations.

4) is based directly on annual maximum data and thus does not depend on the questionable assumption (inherent in rainfall-runoff modeling) that the T-year storm produces the T-year flood event.

Strictly speaking, the regression equations are subject to several limitations:

1) limited to watersheds greater than 1 mi^2 (2.6 km^2) in area (the smallest watershed in the underlying data set)
2) flatter than 260 ft/mi (50 m/km) in Benson slope
3) wetlands (by National Wetlands Inventory) less than 27% of total area.
4) watersheds should be rural, undeveloped, and unregulated.

However, regression estimates can be calculated for watersheds outside these limits because the equations are so simple to apply. Much of the basic data preparation for USGS is also needed for Rational and Modeling. Therefore, the USGS estimate should always be calculated. Even for small watersheds, USGS can be used as one piece of information to judge the reasonableness of other estimates provided the watersheds are only marginally outside the limits of strict applicability.

Rational Method

Rational Method has been in use for 150 years and remains the tool of choice for hydrologic design on small watersheds and paved surfaces. It is impossible to assign a precise upper limit on watershed size for reliable Rational application. References cite upper limits ranging from 200 acres (Dunne and Leopold, 1978, p. 298) and "several hundred" acres (Viessman, et al, 1977, p. 512) to 1000 acres (WSDOT, 1997, p. 2-3) (with 1 km^2 approximately = 250 ac). General consensus is that best results are obtained when area is less than 200 ac (0.8 km^2; WSDOT suggests an upper limit of 100 ac (0.4 km^2) for best accuracy) and the surface is largely impervious or, failing that, at least homogeneous. Indeed, under such conditions Rational is likely to be as good or better than more complicated methods. For the purposes of MDOT design, Rational estimates should be calculated for all watersheds smaller than 640 ac (1 mi^2 = 2.6 km^2). At the lower end of this range, Rational estimates should be most reliable. Above 320 ac (0.5 mi^2 = 1.3 km^2, the designer should combine Rational, USGS and other estimates in some manner (not necessarily simple averaging) to arrive at a single design flow. As watershed area approaches 1 mi^2 (= 640 ac = 2.6 km^2), greater emphasis should be given to the USGS estimate. Rational estimates should not be used for areas larger than 1 mi^2.

Rainfall-Runoff Modeling

Rainfall-Runoff Modeling can be a useful technique under certain well-defined circumstances. However, it is wrong to assume that because these models purportedly capture more detailed hydrology, they are somehow more accurate. The assumptions underlying much of TR-20 hydrology are almost as severe as those underpinning Rational Method. Furthermore, the paucity of flow and other process-based hydrologic data in most highway design situations requires major assumptions about parameter values and distributions. With Rational Method the

assumptions and simplifications are impossible to ignore, whereas in TR-20 it is easy to be seduced by the "complexity" into believing that a higher degree of accuracy has been achieved. Therefore, TR-20 (and other rainfall-runoff) modeling should only be used when Rational and USGS are clearly inappropriate. Some of these situations are

1) watershed is too heterogeneous for Rational application
2) watershed is heavily developed
3) hydrograph routing is required (as in detention pond design and some culvert analysis)
4) watershed is between 320 - 640 ac (0.5 - 1 mi^2; 1.3 - 2.6 km^2) and other estimates are highly inconsistent
5) watershed is smaller than 640 ac and has significant storage

The different methods for peak flow estimation will now be described in more detail. Following these descriptions, suggestions will be given for combining several estimates into a single design flow. As this document is primarily a manual for MODT highway design staff, emphasis will be given to the Rational Method. Modeling is a specialized topic that is beyond the scope of this manual.

12-2.04 USGS Regression Equations

Introduction

Regression equations are the preferred method for peak flow estimation, provided they are appropriate for the given situation (see table above). Generally speaking, for undeveloped watersheds larger than 1 mi^2 (640 ac = 2.6 km^2), USGS regression should be the only method employed when peak flows are needed.

Advantages of regression equations are

1) cost-efficient
2) minimal data requirements (just area and percentage wetlands)
3) uncertainty (error) is quantified
4) more accurate than modeling
5) based on actual flood events as opposed to design storms

Primary limitations of the Maine equations are

1) accuracy decreases in an unknown way as watersheds become smaller than 1 mi^2 (640 ac = 2.6 km^2)
2) accuracy decreases in an unknown way when watershed characteristics are determined with methods different from those used in the original regression study
3) give only peak flow, not complete hydrograph

4) best suited to undeveloped and unregulated watersheds, though correction for urbanization is available
5) ill-suited to "pre-development/post-development" applications

Therefore, for undeveloped watersheds larger than 1 mi^2 (= 640 ac = 2.6 km^2), USGS regression should be the only method employed when peak flows are needed. For watersheds smaller than 640 ac, Rational and USGS should both be calculated. Instructions for combining estimates are given in a later section. Since the equations calculate only the peak flow, they are inappropriate for storage routing applications and in these situations modeling will be necessary.

Regression Equations and Their Coefficients

Regression equations derive their strength from a large database of annual peak flow records. No other method is so rooted in real Maine data. The current USGS equations are based on records from 70 stations, each with 10 or more years of record. There is just one set of equations for the entire State of Maine, of the form

$$Q_T = b(A)^a 10^{-w(W)}$$

Where	T	=	design flood recurrence interval (years)
	b,a,w	=	coefficients dependent on T value
	Q	=	peak flow (m^3/s)
	A	=	watershed area, km^2
	W	=	percentage (%) wetlands as determined from National Wetlands Inventory (NWI) maps

The USGS equations were developed in the metric system. Therefore, watershed area should be converted to [km^2] before applying the equations:

$$A\,[km^2] = 2.59 \times A\,[mi^2]\ .$$

Similarly, the resulting Q values in [m^3/s] should be converted to [ft^3/s]:

$$Q\,[ft^3/s] = 35.29 \times Q\,[m^3/s]\ .$$

The coefficients and associated estimate error bounds are summarized in Table 12-2.2.

The effect of NWI storage in these equations is to reduce Q_T as compared to the absence of storage. Wetland hydrology is complex and this simplistic accounting may not offer an accurate picture of the behavior of a particular watershed.

Table 12-2.2: Full USGS regression equations[1] and their accuracy for estimating peak flows Q for rural ungaged, unregulated streams watersheds in Maine (from Table 3, Hodgkins, 1999)

T	b	a	w	Standard Error (%)	PRESS Error (%)	Equivalent Years Record
2	1.075	0.848	0.0266	40.6 to -28.9	42.2 to -29.7	1.82
5	1.952	0.820	0.0288	41.9 to -29.5	43.5 to -30.3	2.47
10	2.674	0.806	0.0300	42.9 to -30.0	45.2 to -31.1	3.20
25	3.740	0.790	0.0312	45.2 to -31.1	48.3 to -32.5	4.14
50	4.637	0.780	0.0320	46.9 to -31.9	51.0 to -33.8	4.78
100	5.629	0.771	0.0326	48.6 to -32.7	53.5 to -34.8	5.37
500	8.283	0.754	0.0340	53.5 to -34.8	60.0 to -37.5	6.41

[1]equation of form $Q_T = b(A)^a 10^{-w(W)}$; Q in (m^3/s), A in (km^2), and W as percentage

Area and wetlands are called "predictor variables" because they are used to predict or calculate the "response variable" Q_T. Strictly speaking, regression equations should only be used when the predictor variables (in this case, area and wetlands) of a candidate watershed fall within the range of predictor variables in the underlying database. The limits for the Maine annual maximum database follow in Table 12-2.3.

Table 12.2-3: Limits for Peak Flow Regression Applicability

Minimum	Parameter	Maximum
1 mi^2 = 640 ac = 2.6 km^2	< A <	1660 mi^2 = 4,300 km^2
0.7	< W (%) <	27
----	< Benson Slope <	260 ft/mi = 50 m/km

Determining Watershed Characteristics for Regression Calculation

In general, watershed characteristics should be determined in the same way as they were determined in the original regression study (Hodgkins, 1999). Despite this general guidance, it is recognized that occasionally watershed characteristics may be determined in a different manner. These exceptional cases should be clearly noted, along with the particular methods used to determine watershed variables.

Area and Boundary Delineation: USGS topographic maps (1:24000 scale) were the sources of information for development of the regression equations and therefore these maps are the source of choice of all applications.

Wetlands: It is critical that wetlands percentage be taken from the National Wetlands Inventory (NWI) 1:24000 map series for the State of Maine (U.S. Department of Interior, various years). Wetlands should not be measured from topographic maps, aerial photos, site-specific wetlands aps, or other sources, when NWI maps are available at resolution comparable to watershed scale.

Slope: Slope is not a predictor variable in the USGS (1999) regression equations. However, it is used to determine the applicability of these equations, since they are not applicable to steep catchments (S > 250 ft/mi = 50 m/km). Watershed slope (Benson, 1962) is calculated for the "10-85" flow path. The hydraulically longest path from outlet to divide is identified (longest in the sense of requiring the most time for water to move from divide to outlet). The 10-85 segment starts at the point that is 10% (of total path length) from the outlet and ends at the 85% point.

12-2.05 Rational Method

The Rational Formula has been in use for over 150 years for calculating peak flow. While best suited to small urban drainages, it is also used for small rural catchments. Despite its simplicity, it is essentially a simple deterministic rainfall-runoff model. Pilgrim and Cordery (in Maidment, 1992) and McCuen (1989) give modern presentations of this venerable method. The general formula is

$$Q = \mu C i A$$

where Q = peak runoff (ft^3/s or m^3/s)
μ = unit conversion factor (1 for U.S. Customary; 0.28 for metric)
C = runoff coefficient (dimensionless; $0 < C < 1$)
i = rainfall intensity (in/hr or mm/hr)
A = watershed area (ac or km^2)

Runoff Coefficient

The runoff coefficient is commonly interpreted as the ratio of peak runoff output to (volumetric) rainfall rate. With this understanding, and when the Rational formula is used as a rainfall-runoff model to simulate real events, C is a deterministic watershed parameter that effectively lumps numerous physically meaningful watershed parameters. The runoff coefficient C depends on land use, cover type, slope, and rain event magnitude.

Rainfall Intensity

Rainfall intensity i is assumed uniform over the catchment and constant for the storm duration t_r. For peak flow calculation, the duration t_r in turn is set equal to the catchment time of concentration t_c (time for entire catchment to produce runoff at the outlet) because peak flow is achieved for storm durations $t_r \geq t_c$. Intensity is a random variable and is determined from location-specific intensity-duration-frequency (IDF) curves. For a specified t_c and event return period T, the IDF curve gives the design average storm intensity.

The IDF curves from the January 1994 MDOT Drainage Design Manual have been fit to the functional form

$$i = a/(t_r + c)^b$$

where

i = average rainfall intensity, (in/hr or mm/hr), for duration t_r
t_d = rainfall duration (min)
a,b,c = equation coefficients, specific by location and return period

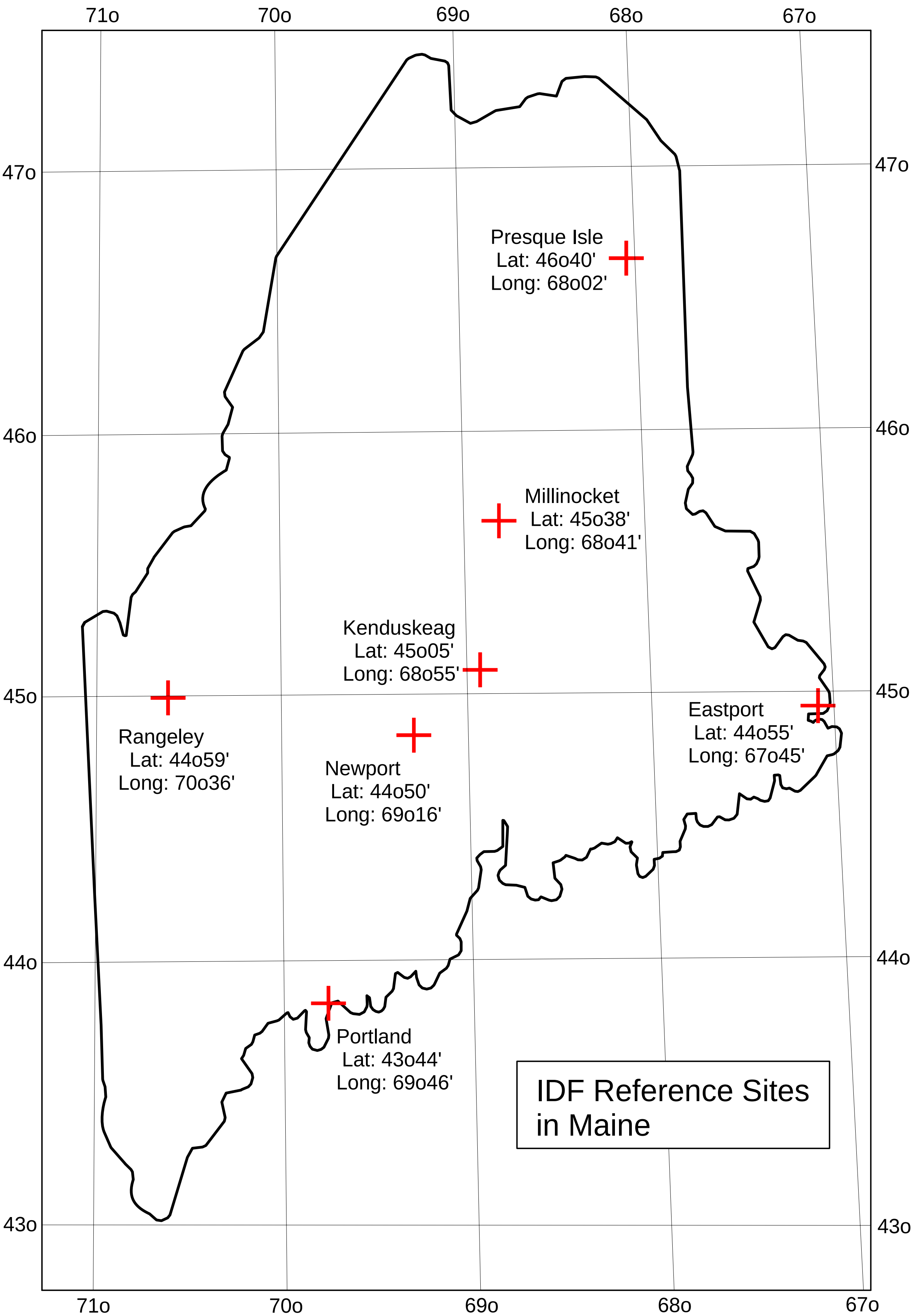
Coefficient values are summarized in Table 12-2.4 for six locations in Maine. The corresponding 10- and 50-year curves are graphed in Figures 12-2.1a 12-2.1f. Note that rainfall intensity decreases as duration increases. To obtain IDF equations in (mm/hr), multiply the "a" coefficients in Table 12-2.4 by 25.4.

Table 12-2.4: Coefficients for Maine Intensity-Duration-Frequency (IDF) Curves (U.S. Customary Units)

	Portland	Eastport	Rangeley	Presque Isle	Newport	Millinocket
2 yr - a	25.76	16.031	21.26	30.91	25.12	28.68
b	0.746	0.683	0.720	0.859	0.767	0.812
c	7.141	4.863	4.224	7.084	6.714	7.724
10 yr - a	30.82	23.77	38.96	40.04	31.66	33.49
b	0.686	0.665	0.754	0.807	0.722	0.744
c	8.133	6.466	8.208	8.357	7.158	8.172
50 yr - a	41.34	36.00	60.78	55.09	45.74	50.41
b	0.691	0.688	0.790	0.809	0.738	0.769
c	8.956	7.744	10.019	9.779	8.803	9.512
100 yr - a	47.59	41.17	82.52	62.59	48.69	44.54
b	0.698	0.691	0.826	0.810	0.726	0.721
c	9.921	8.452	12.368	10.01	8.478	7.727

Note: IDF equation is $i = a/(t_d + c)^b$, i and a in (in/hr), t_d and c in (min); a[mm/hr] = 25.4 x a[in/hr]

Figure 12-2.1a



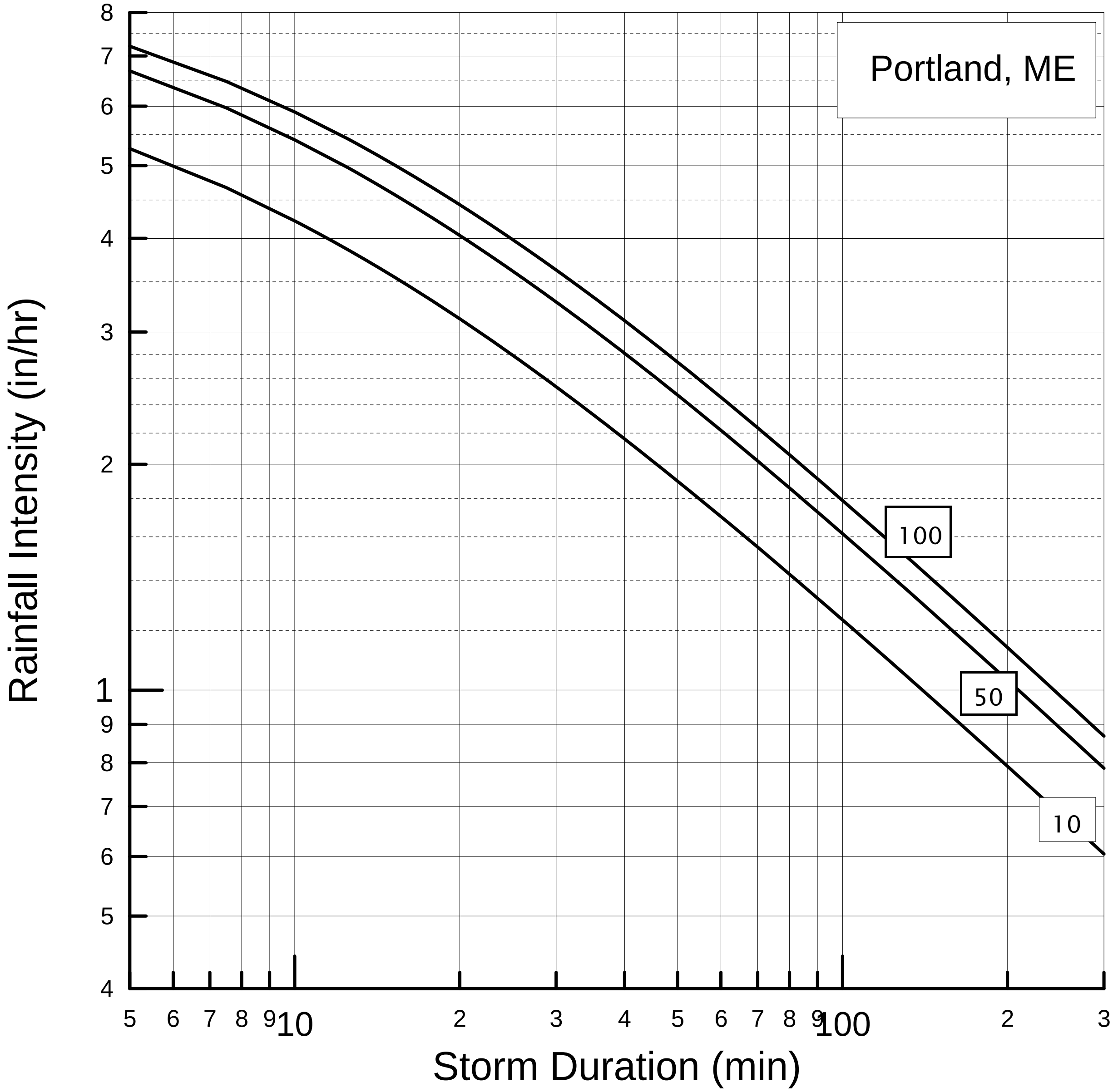


Figure 12-2.1b: Intensity-Duration-Frequency Curve, Portland, Maine (labeled return period in years).

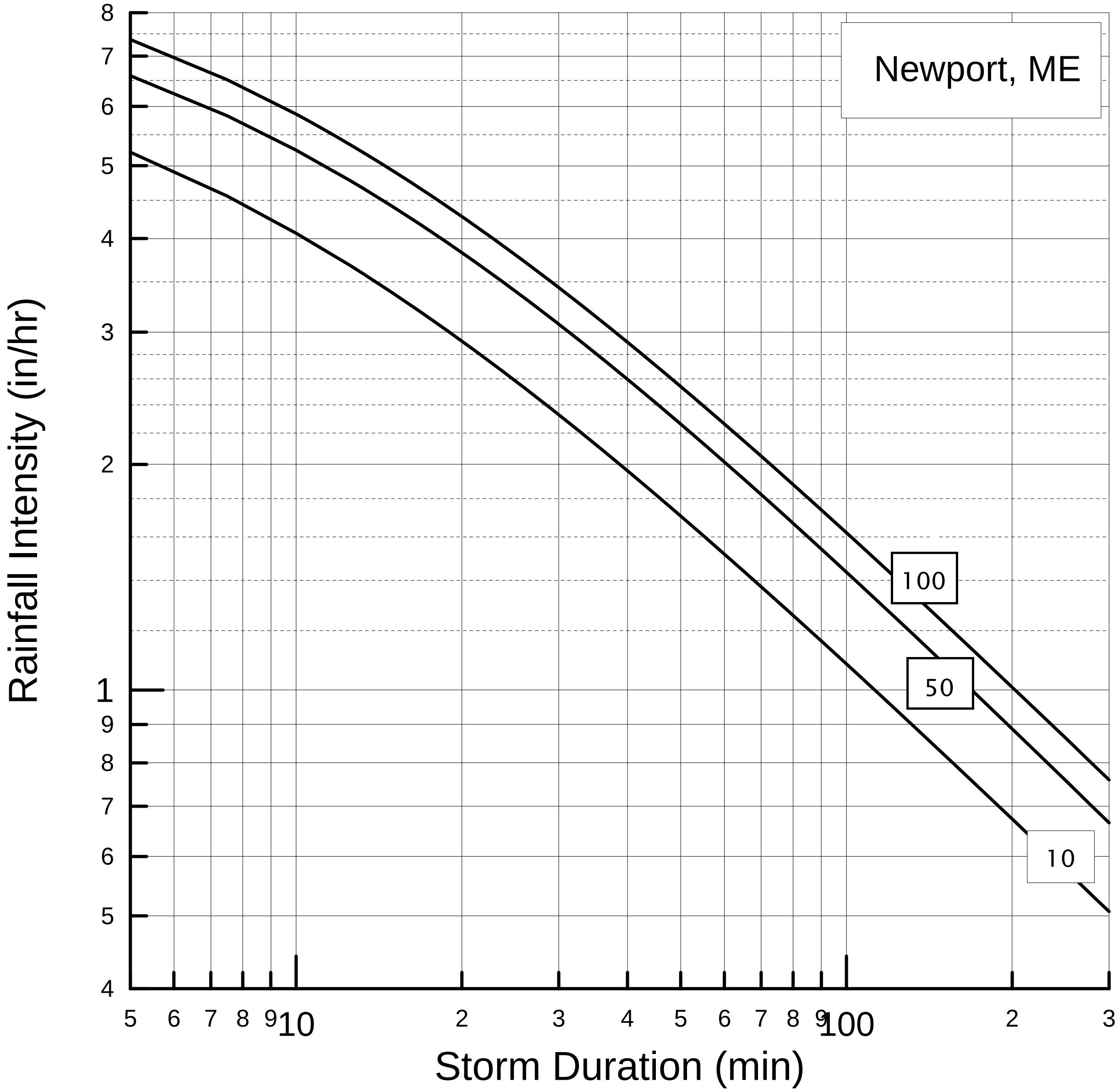


Figure 12-2.1c: Intensity-Duration-Frequency Curve, Newport, Maine (labeled return period in years).

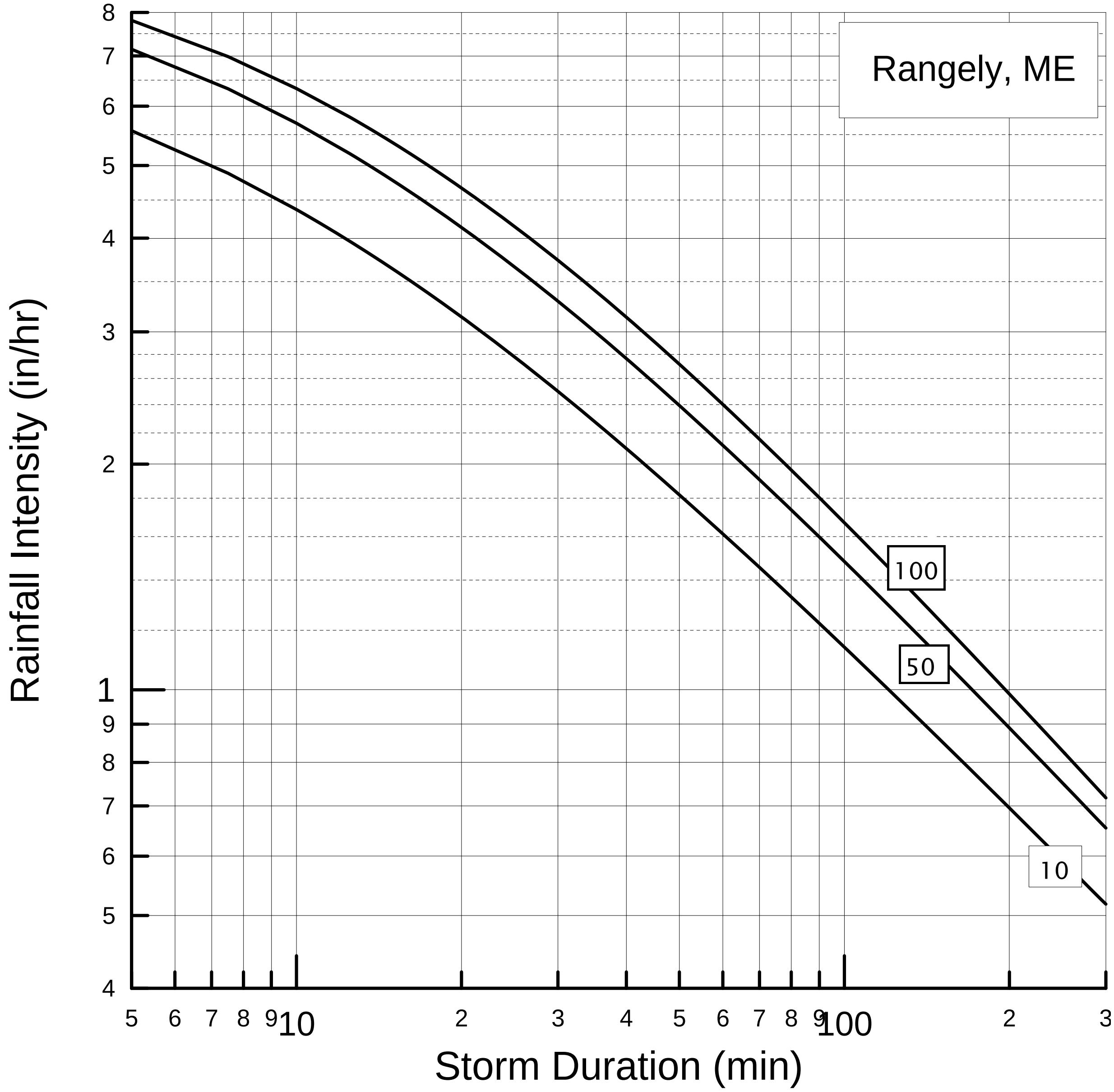


Figure 12-2.1d: Intensity-Duration-Frequency Curve, Rangely, Maine (labeled return period in years).

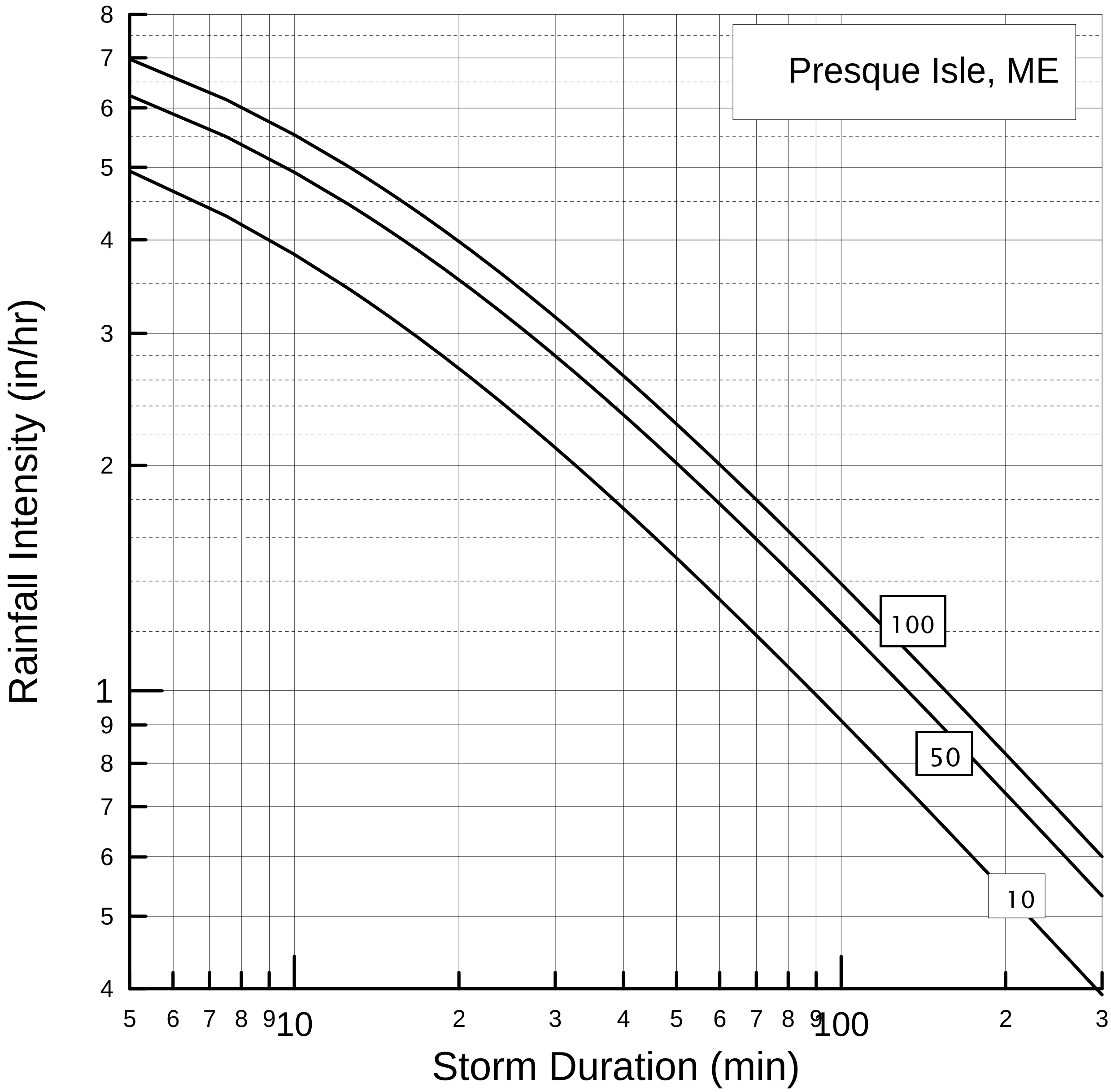


Figure 12-2.1e: Intensity-Duration-Frequency Curve, Presque Isle, Maine (labeled return period in years).

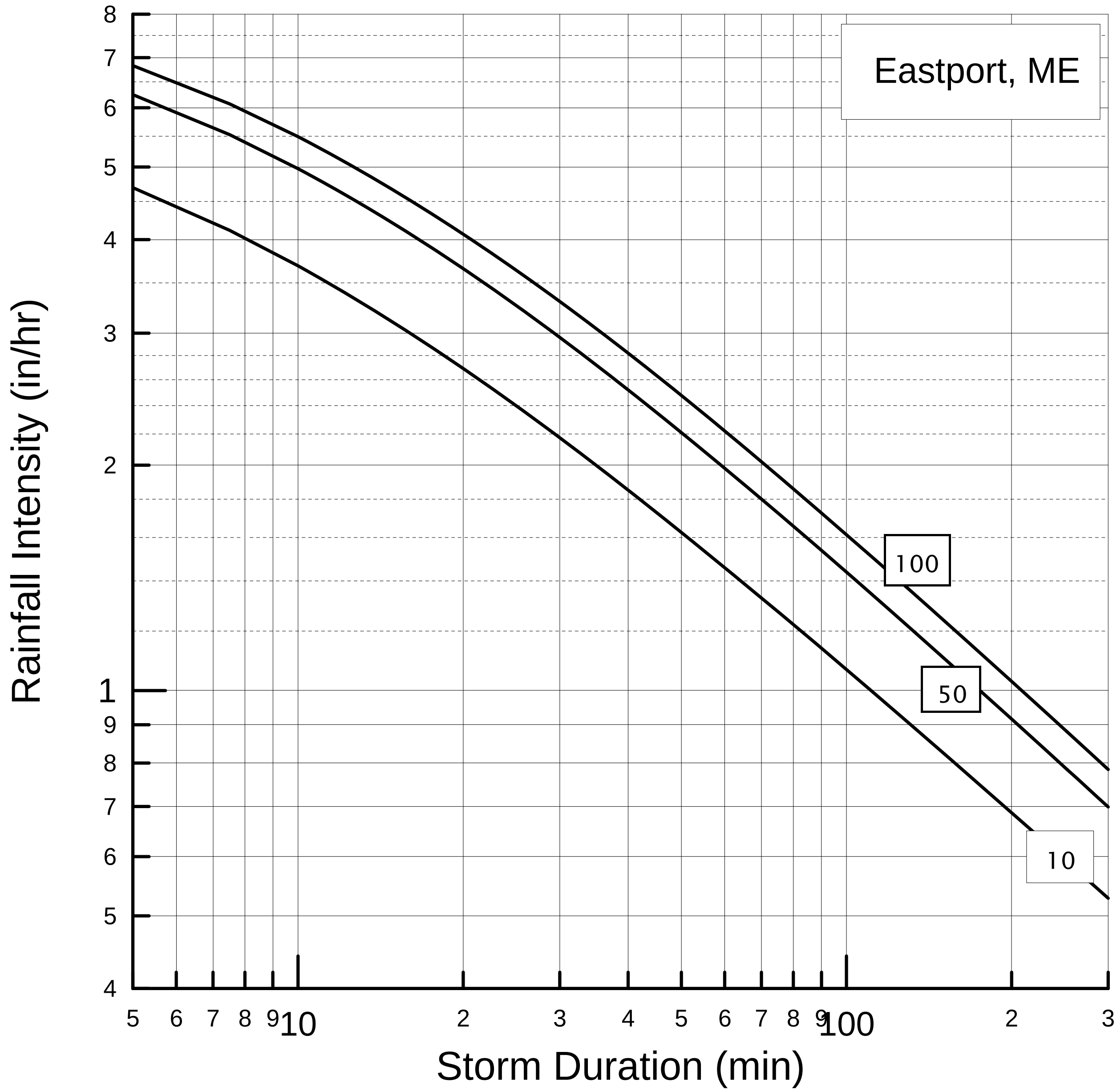


Figure 12-2.1f: Intensity-Duration-Frequency Curve, Eastport, Maine (labeled return period in years).

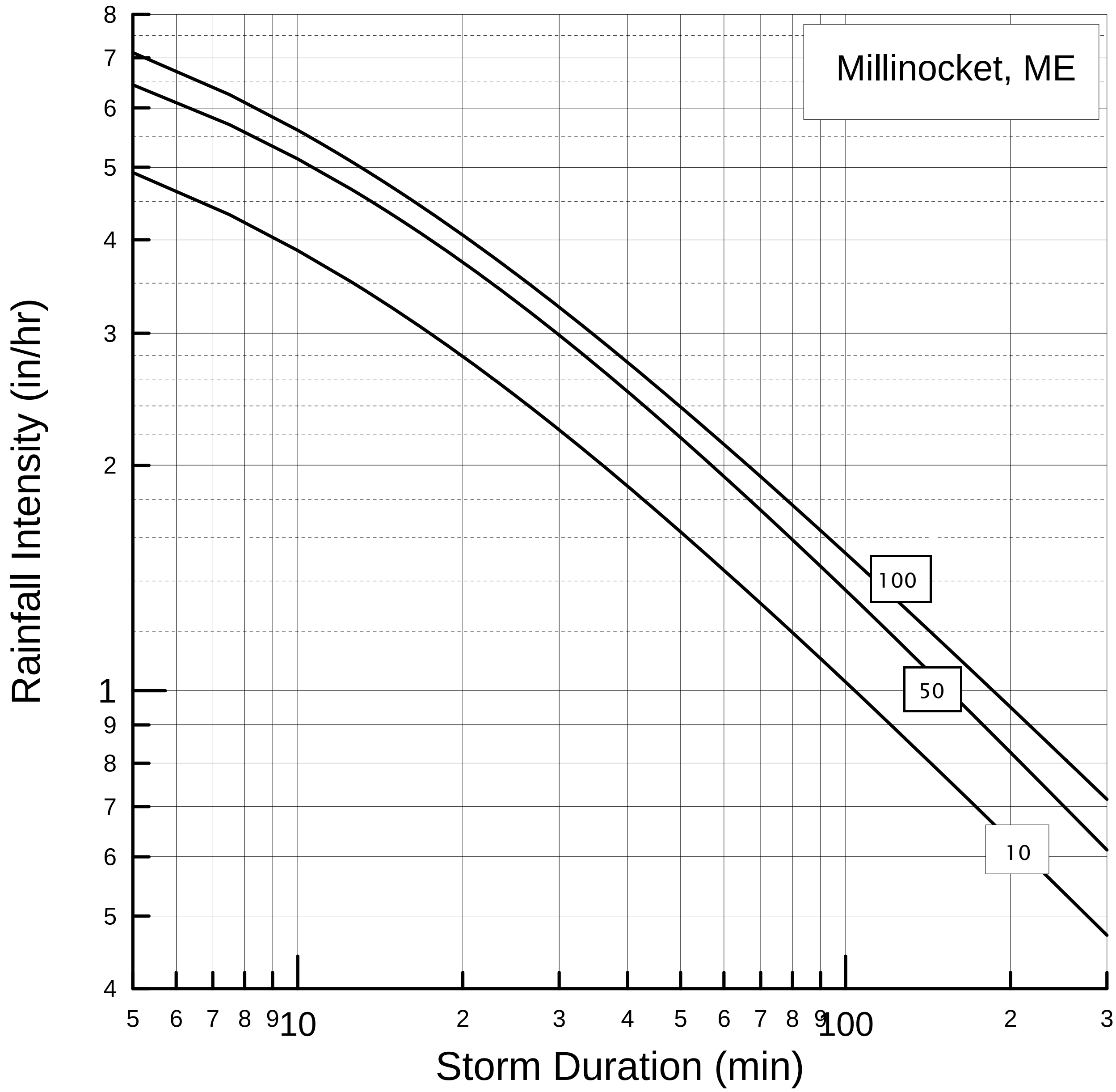


Figure 12-2.1g: Intensity-Duration-Frequency Curve, Millinocket, Maine (labeled return period in years).

Time of Concentration

For a uniform, steady rainfall, time of concentration t_c is the time for the entire watershed to produce runoff at the outlet. A physically based conceptual definition of time of concentration t_c is the time for a drop falling on the *hydraulically* most remote part of a watershed to reach the outlet. By the time this drop reaches the outlet, runoff from every other point in the watershed has also reached the outlet, and thus runoff peaks for a steady rain with duration $t_r = t_c$. Thus, the hydraulically longest flow path is that which has the longest travel time.

According to this definition, a flow path must be delineated before t_c can be calculated. A short distance over a flat, rough area may have a longer travel time than over a longer but steeper and smoother area. As a practical matter, flow paths will be determined on the basis of physical length in most cases. However, the conceptual definition should be kept in mind when unusual situations are encountered. Assumptions can always be checked by calculation.

The essence of the Rational Method (as opposed to the Rational Formula) is the decision to set design storm duration t_r equal to time of concentration t_c. Choosing an appropriate design rainfall is a matter of determining t_c: once t_c is known, intensity i follows directly from the IDF curve, by formula or look-up, with storm duration t_r equal to t_c. In highway hydrology t_c is usually taken as a deterministic watershed parameter. Smaller durations (equal to t_c in Rational Method) correspond to higher intensities for a given return period. Underestimating t_c leads to overestimating Q and thus to overdesign of hydraulic structures. Thus, a reasonable t_c value is critical to calculating reasonable design flows. Conversely, overestimating t_c leads to lower flow estimates and underdesign.

Hydraulics of t_c: The conceptual definition of t_c is at the heart of the "TR-55 approach" (TR-55 (NRCS, 1986) is a simplified version of the TR-20 rainfall-runoff event mode). This approach is recommended for MDOT hydrologic practice. A raindrop starting at the hydraulically most remote point in the watershed is assumed to follow a flow path that consists of some combination of sheet flow, shallow concentrated flow, and channel flow. All three types of flow need not be present. Manning's equation for open channel flow is typically used to calculate the travel time T_t of flow in each flow segment (the travel time is identically the time of concentration of the watershed component). The sum of component travel times gives the watershed time of concentration:

$$t_c = T_{t|sheet} + T_{t|conc} + T_{t|channel}$$

Since the calculations are hydraulics-based, physically meaningful parameters are used: roughness n, slope S, hydraulic radius (surrogate for depth of flow) R_h, and length of flow L. While these parameters are physically meaningful and are not empirical coefficients determined by regression, in practice their determination is somewhat problematic.

Velocity Method for Time of Concentration

The velocity method uses the definition of velocity to calculate travel time:

$$v = L/T_t$$
$$T_t = L/v$$

Manning's equation (in consistent units) is used to calculate velocity:

$$v = \lambda R_h^{2/3} S^{1/2}/n$$

where v = velocity (ft/s or m/s)
λ = unit conversion factor (1.486 for U.S. Customary; 1 for metric)
R_h = hydraulic radius (ft or m) = A_{flow}/P_{wet}
A_{flow} = flow cross-sectional area (ft^2 or m^2)
P_{wet} = wetted flow perimeter (ft or m)
S = slope (dimensionless; ft/ft or m/m)
n = Manning's roughness parameter (value independent of units)

For sheet flow and shallow concentrated flow, the height of roughness elements is on the same order as depth of flow. Furthermore, depth of flow is small and is difficult to measure or calculate reliably. Therefore, the hydraulic radius and roughness are often lumped into a single conveyance parameter k,

$$k = \lambda R_h^{2/3}/n \quad (\text{ft}^{2/3} \text{ or m}^{2/3})$$

so that

$$v = kS^{1/2}$$

$$T_t = L/v = \{L/S^{1/2}\}/k$$

(Note that k (m$^{2/3}$) = k (ft$^{2/3}$)/3.28.)

The "k formulation" is typically limited to sheet flow and shallow concentrated flow; in channel flow, the hydraulic radius R_h can be estimated explicitly.

Sheet Flow: Sheet flow is flow over planar surfaces such as paved areas and fields. The standard assumption is that it occurs primarily in catchment upland areas. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact, drag over the surface, obstacles to flow (such as litter, crop ridges, rocks, etc), and erosion and transport of sediment. Appropriate n values range from 0.01 for smooth paved surfaces to 0.40 for forest floors. Flow depth (hydraulic radius R_h) should ordinarily not exceed 2 in (50 mm).

Sheet flow is often the "slowest" flow component in the TR-55 conceptual model and thus overall watershed t_c is very sensitive to the sheet flow parameters. Length of sheet flow is particularly problematic. The questionable practice of assuming a "standard" flow length is widespread but cannot be justified. A value of 300 ft (90 m) is cited in TR-55 as being an upper limit; unfortunately this value has crept into practice as a default standard. In fact, this value is probably too large in most situations, possibly justified only on flat, uniform surfaces. Large flow lengths lead to overestimation of t_c, underestimation of rainfall intensity i, underestimation of the design flow, and ultimately underdesign of the hydraulic structure. Assessment of reasonable sheet flow lengths should be part of the hydrologic site inspection.

Exact Kinematic Wave Solution for Sheet Flow: The best physically-based estimate for sheet flow (overland) flow travel time is the Kinematic Wave (KW) approach, which in turn is based on Manning's equation. The method is computationally complex and for manual calculations the approximate solution, also presented here, may be preferred. An advantage of the exact solution is that it captures the dependence of travel time on event return period; more extreme events give a smaller time of concentration.

The KW expression for travel time is derived from the general velocity method by assuming that the depth of sheet flow (essentially the hydraulic radius) is equal to the product of rain intensity and sheet flow travel time $T_{t|sheet}$ for duration $t_r \geq T_{t|sheet}$:

$$R_h = iT_{t|sheet}$$

Substituting into Manning's equation gives

$$v = \lambda(iT_{t|sheet})^{2/3}S^{1/2}/n$$

Continuing with the velocity expression for sheet flow travel time and solving for t_c,

$$T_{t|sheet} = L/v = \{nL/\lambda S^{1/2}\}(iT_{t|sheet})^{2/3}$$

$$T_{t|sheet} = \{nL/\lambda S^{0.5}\}^{0.6}/i^{0.4}$$

where all physical quantities are in consistent units of (ft) or (m) and (s).

For the familiar units of (in/hr) for i and (min) for $T_{t|sheet}$, the equation becomes

$$T_{t|sheet} = 0.94\{nL/S^{0.5}\}^{0.6}/i^{0.4}$$

For the metric units of (mm/hr) for i and (min) for $T_{t|sheet}$, the coefficient 0.94 is replaced by 7.

Note that the factor $0.94\{nL/S^{0.5}\}^{0.6}$ and (and $7\{nL/S^{0.5}\}^{0.6}$ in metric) are characteristic of a specified sheet flow path and as such are watershed parameters.

This is a non-linear equation and requires iterative solution for $T_{t|sheet}$ because intensity i is a function of $T_{t|sheet}$ (equal to rainfall duration) on the IDF curve. This equation is easily solved using standard root-finding methods in a specially prepared spreadsheet (including MaineDOT hydrology EXCEL applications). Manual calculation by "Picard iteration" (successive approximation, a form of repetitive calculation) is also simple, though tedious for more than a few watersheds. A starting value of travel time is assumed, say $T_{t|sheet}$ = 10 min, along with a corresponding i value by calculation or look-up. Then a new $T_{t|sheet}$ value is calculated using the KW equation above. This $T_{t|sheet}$ value is used in turn to determine (by IDF calculation or chart look-up) a new i value. The process is repeated until the i and $T_{t|sheet}$ values converge to steady values.

Example: Determine sheet flow travel time by Kinematic Wave model for a flow path with L = 100 ft and S = 0.01 on rough grass in the Portland area.

For rough grass, n = 0.4. Employ Picard iteration (successive approximation) to calculate $T_{t|sheet}$. Assume a starting value of $T_{t|sheet;0}$ = 5 min.

Sheet flow segment constant: $0.94\{nL/S^{0.5}\}^{0.6} = 0.94\{0.4 \text{ x } 100/0.01^{0.5}\}^{0.6} = 34.23$
Portland 10-year IDF curve: $i = 30.82/(t+8.133)^{0.686}$

Iteration	$T_{t\|sheet} = 34.23/i^{0.4}$ (min)	i (in/hr) by calculation or look-up
0	5	5.27
1	$34.23/5.27^{0.4} = 17.61$	3.32
2	$34.23/3.32^{0.4} = 21.18$	3.04
3	$34.23/3.04^{0.4} = 21.95$	2.98
4	$34.23/2.98^{0.4} = 22.11$	2.97
5	$34.23/2.97^{0.4} = 22.14$	2.97

For this sheet flow path, the final estimate is a travel time of 22.1 min.

Approximate Kinematic Wave Solution for Sheet Flow: The approximate KW solution is

$$T_t = (0.42/P_2^{1/2})(nL/S^{1/2})^{4/5}$$

where P_2 = 2-yr 24-hr rainfall depth (in; see Table 12-2.8).

This equation is suitable for manual calculations. The difference between the exact and approximate solutions becomes more pronounced as the design return period gets larger.

Shallow Concentrated Flow: Shallow concentrated flow commences at the point where sheet flow is too inefficient to transport the volume of water originating upstream of that point. Shallow concentrated flow is visualized as occurring in numerous and closely spaced small channels and rivulets. Depth of flow is still small but Manning's "n" is smaller than in sheet flow, making for faster flow velocity and smaller travel time T_t as compared to sheet flow. In agricultural areas tillage will control the direction of flow, in which case aerial photos and site inspections are essential. Table 12-2.7 can be used to estimate R_h and n; values of 2 in (50 mm) and 0.05, respectively, are reasonable starting estimates.

Channel Flow: Open channels are assumed to begin where surveyed cross section information has been obtained, where channels and singular drainage features are visible on aerial photos, or where blue lines (indicating streams) appear on USGS quadrangle sheets. In general, the use of aerial photos will result in longer channels than USGS topographic maps alone. Both Manning's roughness and hydraulic radius are channel-specific and should be based on actual observation and measurement. Standard practice in hydrologic studies is to base hydraulic radius on bank-full conditions (approximate 2-year event), even though the 50-year design event will be over the bank. Hydraulic analysis can be used to refine R_h is channel and overbank geometry data are available. Roadside ditches should be treated as open channels.

<u>Watershed Area</u>

Area is a straightforward parameter and requires little in the way of interpretation. The biggest complication in highway design work is that the small watersheds suitable for Rational method typically extend beyond the project boundary and thus off the project plans and topography. Yet they can also be too small for reliable delineation from standard USGS 7.5 minute topography, so watershed delineation is often based on aerial photo interpretation. Field checking of delineations is particularly critical for flat watersheds. Also, ditching and crosspipes can significantly effect delineation and flow paths, as compared to simple delineation based on topography alone.

<u>Rational Method Parameter Values</u>

Tables 12-2.5 – 12-2.7 are taken from McCuen (1989) and provide guidance in choosing parameter values for use in Rational Method calculations. Table 12-2.5 correlates C values to land use, slope, and Natural Resources Conservation Service (NRCS; formerly Soil Conservation Service (SCS)) hydrologic soil group. Hydrologic soil group is a soil classification system developed by NRCS based on a soil's long-term infiltration rate, in turn a function of soil composition, depth, and slope. Table 12-2.5 should be used as the primary reference for C values, in order to preserve some consistency between application of Rational Method and NRCS methods (TR-55 and TR-20). A standard source for determining soil types on a project is the series of NRCS county soil surveys; site-specific soil surveys may also be available. Table 12-2.5 is notable for its treatment of C as a random variable, dependent on event return period. This is more realistic than the usual assumption that C (and runoff curve number) is a fixed, deterministic watershed parameter. Table 12-2.6 that follows is a compendium of C values by land use only and is useful as a further check on values used in analysis. NRCS models utilize

an analogous parameter, the runoff curve number (RCN). Values are not tabulated here; the reader is referred to standard references.

Table 12-2.7 lists representative values of hydraulic radius R_h, Manning's roughness n, and composite factor k for land uses and flow regimes encountered in Rational Method application. Flow depth and R_h are essentially identical in sheet flow. This equivalence weakens as flow channelizes, in which case the definition of hydraulic radius ($R_h = A/P$) must be utilized for real flow channels. For shallow concentrated flow it is sufficient to assume R_h on the order of 2 in (50 mm). The travel times for shallow concentrated flow and channel flow are generally much shorter than for sheet flow, so that the overall watershed t_c, intensity i, and resultant Q are relatively insensitive to these components. In cases where all three flow components have roughly equal travel times, sensitivity analysis should be performed on the different parameters.

As noted above, sheet flow travel time is particularly sensitive to length of flow. The associated slope is also important. On typical hillslope profiles, sheet flow originating at the watershed divide will often have a slope less than in the mid-slope region. These distinctions should not be lost. Channel flow length is fairly easy to identify from topographic maps and aerial photos. Shallow concentrated flow is difficult to identify directly and is often treated as what is "left over" after sheet flow and channel flow paths have been identified. Travel times in shallow concentrated flow and channel flow are usually much shorter than sheet flow, so travel times are not very sensitive to channelized and concentrated flow lengths.

Table 12-2.5: Runoff Coefficients for Rational Formula by Soil Type and Slope (McCuen, 1989)

	Hydrologic Soil Group											
	A			B			C			D		
Land Use	0-2%	2-6%	>6%	0-2%	2-6%	>6%	0-2%	2-6%	>6%	0-2%	2-6%	>6%
Cultivated Land	0.08 0.14	0.13 0.18	0.16 0.22	0.11 0.16	.015 0.21	0.21 0.28	0.14 0.20	0.19 0.25	0.26 0.34	0.18 0.24	0.23 0.29	0.31 0.41
Pasture	0.12 0.15	0.20 0.25	0.30 0.37	0.18 0.23	0.28 0.34	0.37 0.45	0.24 0.30	0.34 0.42	0.44 0.52	0.30 0.37	0.40 0.50	0.50 0.62
Meadow	0.10 0.14	0.16 0.22	0.25 0.30	0.14 0.20	0.22 0.28	0.30 0.37	0.20 0.26	0.28 0.35	0.36 0.44	0.24 0.30	0.30 0.40	0.40 0.50
Forest	0.05 0.08	0.08 0.11	0.11 0.14	0.08 0.10	0.11 0.14	0.14 0.18	0.10 0.12	0.13 0.16	0.13 0.20	0.12 0.15	0.16 0.20	0.20 0.25
Residential 1/8 ac lot	0.25 0.33	0.28 0.37	0.31 0.40	0.27 0.35	0.30 0.39	0.35 0.44	0.30 0.38	0.33 0.42	0.38 0.49	0.33 0.41	0.36 0.45	0.42 0.54
Residential ¼ ac lot	0.22 0.30	0.26 0.34	0.29 0.37	0.24 0.33	0.29 0.37	0.33 0.42	0.27 0.36	0.31 0.40	0.36 0.47	0.30 0.38	0.34 0.42	0.40 0.52
Residential 1/3 ac lot	0.19 0.28	0.23 0.32	0.26 0.35	0.22 0.30	0.26 0.35	0.30 0.39	0.25 0.33	0.29 0.38	0.34 0.45	0.28 0.39	0.32 0.40	0.29 0.50
Residential ½ ac lot	0.16 0.25	0.20 0.29	0.24 0.32	0.19 0.28	0.23 0.32	0.28 0.36	0.22 0.31	0.27 0.35	0.32 0.42	0.26 0.34	0.30 0.38	0.37 0.48
Residential 1 ac lot	0.14 0.22	0.19 0.26	0.22 0.29	0.17 0.24	0.21 0.28	0.26 0.34	0.20 0.28	0.25 0.32	0.31 0.40	0.24 0.31	0.29 0.35	0.35 0.46
Industrial	0.67 0.85	0.68 0.85	0.68 0.86	0.68 0.85	.068 0.86	0.69 0.86	0.68 0.86	0.69 0.86	0.69 0.87	0.69 0.86	0.69 0.86	0.70 0.88
Commercial	0.71 0.88	0.71 0.88	0.72 0.89	0.71 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.90	0.72 0.89	0.72 0.89	0.72 0.90
Streets	0.70 0.76	0.71 0.77	0.72 0.79	0.71 0.80	0.72 0.82	0.74 0.84	0.72 0.84	0.73 0.85	0.76 0.89	0.73 0.89	0.75 0.91	0.78 0.95
Open Space	0.05 0.11	0.10 0.16	0.14 0.20	0.08 0.14	0.13 0.19	0.19 0.26	0.12 0.18	0.17 0.23	0.24 0.32	0.16 0.22	0.21 0.27	0.28 0.39
Parking	0.85 0.95	0.86 0.96	0.87 0.97	0.85 0.95	0.86 0.96	0.87 0.97	0.85 0.95	0.86 0.96	0.87 0.97	0.85 0.95	0.86 0.96	0.87 0.97

[1] for each land use, first row is for return period $T < 25$ yrs, second row is for $T \geq 25$ yrs.

Table 12-2.6: Runoff Coefficients for the Rational Formula by Land Use (McCuen, 1989)

Land Use	Range of Runoff Coefficients "C"	Recommended Value
Business		
Downtown	0.70 - 0.95	0.85
Neighborhood	0.50 - 0.70	0.60
Residential		
Single-Family	0.30 - 0.50	0.40
Multiunits, detached	0.40 - 0.60	0.50
Multiunits, attached	0.60 - 0.75	0.70
Residential (suburban)	0.25 - 0.40	0.35
Apartment	0.50 - 0.70	0.60
Industrial		
Light	0.50 - 0.80	0.65
Heavy	0.60 - 0.90	0.75
Parks, cemeteries	0.10 - 0.25	0.20
Playgrounds	0.20 - 0.35	0.30
Railroad yard	0.20 - 0.35	0.30
Unimproved	0.10 - 0.30	0.20
Pavement		
Asphaltic and Concrete	0.70 - 0.95	0.85
Brick	0.75 - 0.85	0.80
Roofs	0.75 - 0.95	0.85
Lawns, sandy soil		
Flat, < 2%	0.05 - 0.10	0.08
Average, 2-7%	0.10 - 0.15	0.13
Steep, >7%	0.15 - 0.20	0.18
Lawns, heavy soil		
Flat, <2%	0.13 - 0.17	0.15
Average, 2-7%	0.18 - 0.22	0.20
Steep, > 7%	0.25 - 0.35	0.30

Table 12-2.7: Typical Manning's "n" and Hydraulic Radius Values (McCuen, 1989)

Land Use/Flow Regime	Manning's n	Hydraulic Radius R_h (in)	k ($m^{2/3}$) $= R_h^{2/3}/n$	k ($ft^{2/3}$) $= 1.486R_h^{2/3}/n$
Forest				
Light underbrush	0.4	2.64	0.41	1.4
Heavy ground litter	0.2	2.40	0.77	2.5
Grass				
Bermudagrass	0.41	1.80	0.31	1.0
Dense (Lawns, Playing fields)	0.24	1.44	0.46	1.5
Short	0.15	1.20	0.65	2.1
Short grass pasture	0.025	0.48	2.12	7.0
Conventional tillage				
With residue	0.19	0.72	0.37	1.2
No residue	0.09	0.60	0.67	2.2
Agricultural				
Cultivated straight row	0.04	1.44	2.75	9.1
Contour or strip crop	0.05	0.72	1.39	4.6
Trash fallow	0.045	0.60	1.36	4.5
Rangeland	0.13	0.48	0.41	1.3
Alluvial fans	0.017	0.48	3.11	10.3
Grassed waterways	0.095	12.00	4.77	15.7
Small upland gullies	0.04	6.00	7.13	23.5
Pavement (smooth; sheet flow)	0.011	0.72	6.30	20.8
Pavement (rubble; sheet flow)	0.025	2.40	6.19	20.4
Paved gutter	0.011	2.40	14.07	46.3

Note: $k(m^{2/3}) = k(ft^{2/3})/3.28$

12-2.06 Rainfall-Runoff Modeling

On occasion the standard methods of Rational Method and Regression Model will be insufficient and rainfall-runoff modeling will be preferred. "Modeling" is a shorthand expression for event-based models such as TR-20, HEC-1, or similar models. HydroCad is a proprietary model based on TR-20 hydrology that is easy to use and is particularly popular within the consulting community. Modeling is commonly used in the consulting community, less so within MDOT. Modeling issues, including review of consultant work and execution of in-house models, should be referred to the MDOT Hydrology Section.

The following situations might warrant the use of modeling:

1) complete hydrograph is needed, as in flow routing, storage modeling, and detention storage design
2) watershed is between area limits for Rational and regression methods, and results from those methods are problematic
3) watershed properties are highly variable in space, thus make choice of Rational "C" coefficient difficult
4) watershed displays significant storage characteristics that cannot be captured by the Rational Method
5) outlet point of interest integrates numerous definable subwatersheds of varying characteristics

Modern models (e.g. HydroCad) are probably as easy to implement as Rational Method. As long as the particular merits and shortcomings of a method are recognized, MDOT will accept drainage studies based on any the commonly recognized models and methods. Internal preference will continue to be given to Rational Method.

TR-20 hydrology does not utilize rainfall intensities from IDF curves. Rather, storms are usually constructed from 24-hour cumulative depths according to four different temporal distributions, or "storm types". The Type III storm should generally be used in coastal Maine areas and Type II elsewhere. Table 12-2.8, taken from the Maine DEP Stormwater BMP Guide (1995), gives accepted 24-hour depths for different return periods along with appropriate storm type.

In addition to the design storm, TR-20 includes another climate-related parameter, the antecedent moisture condition (AMC). AMC relates to soil moisture condition, rainfall preceding the design event, and possibly temperature. Unless documented for a specific reason, "average conditions" (AMC II) should be employed.

Table 12-2.8: 24-Hour Duration Rainfall Depths (inches) for Various Return Periods

	Return Period (years)								Annual	Comments
Location	1	2	5	10	25	50	100	500		
Androscoggin	2.5	3.0	3.9	4.6	5.4	6.0	6.5	7.8	45.3	
Aroostook C	2.1	2.1	3.2	3.6	4.2	4.6	5.0	5.9	36.1	Presque Isle
Aroostook N	2.0	2.3	3.0	3.5	4.0	4.4	4.8	5.7	36.1	Ft Kent
Aroostook S	2.2	2.5	3.3	3.8	4.4	4.9	5.3	6.4	39.0	Houlton
Cumberland NW	2.8	3.3	4.3	5.0	5.8	6.4	6.9	8.3	43.4	NW of Rt 11
Cumberland SE	2.5	3.0	4.0	4.7	5.5	6.1	6.7	8.1	44.4	SE of Rt 11
Franklin	2.4	2.9	3.7	4.2	4.9	5.4	5.9	7.0	45.6	
Hancock	2.4	2.7	3.6	4.2	4.9	5.5	6.0	7.2	45.2	
Kennebec	2.4	3.0	3.8	4.4	5.1	5.6	6.1	7.2	41.7	
Knox-Lincoln	2.5	2.9	3.8	4.4	5.1	5.7	6.2	7.4	46.1	
Oxford E	2.5	3.0	4.0	4.6	5.3	5.9	6.4	7.6	43.0	E of Rt 26
Oxford W	3.0	3.5	4.5	5.2	6.0	6.6	7.1	8.4	43.8	W of Rt 26
Penobscot N	2.2	2.5	3.3	3.8	4.4	4.9	5.4	6.4	41.5	N of Can-Atl RR
Penobscot S	2.4	2.7	3.5	4.1	4.8	5.3	5.8	6.9	39.5	S of Can-Atl RR
Piscataquis N	2.2	2.5	3.3	3.8	4.4	4.9	5.3	6.3	38.5	N of Can-Atl RR
Piscataquis S	2.3	2.6	3.4	4.0	4.6	5.1	5.5	6.6	41.0	S of Can-Atl RR
Sagadahoc	2.5	3.0	3.9	4.6	5.4	5.9	6.5	7.8	45.3	
Somerset N	2.2	2.5	3.3	3.8	4.4	4.9	5.3	6.3	37.3	N of Can-Atl RR
Somerset S	2.4	2.7	3.5	4.1	4.7	5.2	5.7	6.8	39.5	S of Can-Atl RR
Waldo	2.5	2.8	3.7	4.3	4.9	5.5	6.0	7.1	47.2	
Washington	2.4	2.5	3.4	4.0	4.8	5.4	5.9	7.1	44.2	
York	2.5	3.0	4.0	4.6	5.4	6.0	6.6	7.8	46.7	

Source: Maine DEP Stormwater BMP Guide, November, 1995.

Note 1: Use Type II Storm for Oxford and Penobscot Counties, excepting towns listed below.

Note 2: Use Type III Storm for all other counties and the following towns in Oxford County (Porter, Brownfield, Hiram, Denmark, Oxford, Hebron, Buckfield, Hartford) and Penobscot County (Dixmont, Newburgh, Hampden, Bangor, Veazie, Orono, Bradley, Clifton, Eddington, Holden, Brewer, Orrington, Plymouth, Etna, Carmel, Hermon, Glenburn, Old Town, Milford, Greenfield).

Note 3: 50-yr depths approximated as mid-point between 25- and 100-yr depths based on log-Normal probability plots.

12-2.07 Calibration and Observation-Based Estimates

Rainfall and runoff data are rarely available for calibration of highway drainage calculations and simulations. Very often the best available site-specific data consists of anecdotal information about high water marks, inundation levels, and their relative frequency. Such information is not suitable for numerical calibration of calculations, but it can be used to judge the reasonableness of the calculations. Every effort should be made to identify specific problems areas prone to flooding and to collect anecdotal information about that flooding. This information can be used with backwater analysis and culvert analysis to independently estimate extreme flows. In the case of flood estimates at locations with existing culverts, the hydrologist should compare calculations against the existing pipe capacity in the context of the pipe history. If calculations indicate flooding while experience suggests acceptable pipe performance, the hydrologist should exercise and document professional judgment in recommending a final design peak flow.

12-2.08 Combining Estimates from Different Methods

Rational and USGS Estimates: Area Weighting

In many projects estimates will be determined by these two methods only. The problem arises for areas in the intermediate range 320 ac < A < 640 ac (0.5 mi^2 < A < 1 mi^2; 1.3 km^2 < A < 2.6 km^2). Barring unusual circumstances, Rational estimates will be used for A < 320 ac and regression estimates will be used for A > 1 mi^2.

Experience and training should provide the basis for determining a single final design value. However, simple area weighting can be used to point towards a final value.

$$Q_T = wQ_{T,U} + (1-w)Q_{T,R} \quad , \quad 320 \text{ ac} < A < 640 \text{ ac}$$

Where $w = (A-320)/320$ (area weight; A = watershed area in ac)

$Q_{T,U}$ = estimate by USGS regression

$Q_{T,R}$ = estimate by Rational method

By this equation, the estimates for smaller watersheds (closer to 320 ac) will be weighted towards the Rational method while the larger watershed (closer to 640 ac) estimates will be weighted towards the regression estimate.

12-2.09 PC-Based Computer Applications

It is expected that most highway drainage calculations will be executed on a PC, using either

- MDOT-developed spreadsheet applications for standard calculations
- dedicated modeling software such as TR-20, HydroCAD, HEC-RAS, HEC-HMS, and HY8
- Computational tools developed independently

HEC-HMS and TR-20 both contain a full implementation of NRCS TR-20 hydrology. However, they are less easy to use in engineering applications than HydroCAD because they do not contain a full range of the engineered hydraulic structures (e.g., culverts, weirs, orifices, etc) commonly utilized in engineering hydrologic design, whereas HydroCAD implements a wide variety of structures directly in the model. Instead, with HEC-HMS and TR-20, structure-specific stage-discharge relations must prepared outside the models and imported.

MDOT will accept analyses completed with recognized hydrology and hydraulic software, though the use of freely available public domain software is encouraged. All data files and spreadsheet files should be submitted in digital format with a hydrology report. While independently developed tools may be accepted, MDOT reserves the right to require use of standard models and MDOT spreadsheets.

12-2.10 Documentation of Hydrologic Studies

This guidance is directed towards documentation of TR20-type rainfall-runoff modeling studies. It is also generally applicable to other methods of hydrologic analysis, though it may differ in details. Analysis by Rational Method or regression equations may require less detail. The intent of this guidance is to encourage hydrology reports that can be efficiently reviewed for compliance with MDOT drainage and design policy. Expected benefits of this effort are a more uniform standard of reporting and a higher standard of self-review by consultants prior to submittal to MDOT. MDOT understands that individual reports may vary somewhat from this suggested outline. The following describes the format and minimum information acceptable to MDOT for review and action.

Supervision: Hydrologic studies should be executed under the direct supervision and involvement of a Maine Professional Engineer with demonstrated education and competence in hydrology and hydraulics. The engineer or hydrologist in responsible charge should sign the report cover letter, thereby declaring mastery of and responsibility for the contents of the report.

Report Checklist: A checklist of report format and contents follows this guidance as Table 12-2.9. This checklist should be completed and inserted immediately following the report title page.

Executive Summary: A one-page executive summary of the analysis, major results, and design implications should be prepared.

Introduction: The report proper should begin with a brief description of the project and an explanation of why a hydrologic analysis is being performed. Significant hydrologic features of the project should be noted. If site hydrology is to be changed in any way, these changes should be summarized. All individuals contributing to the analysis should be identified by name and title, along with their roles in the analysis.

Hydrologic Site Description: The site should be described from a hydrologic perspective. Drainage features, topography, soils, geology, surface water, and ground water should be noted as appropriate to the analysis. Existing hydrologic conditions and expected changes, in the absence of any mitigation measures, should be discussed. The need for and effects of mitigation should also be described. The narrative description should be supported by clear and informative figures and tables.

Figures are intended to bring out the important hydrologic features only and therefore should not contain extraneous design information pertinent only to other aspects of the project. Figures should be 8.5” x 11” or 11” x 17”, unless otherwise instructed. At a minimum, figures should consist of

- site located on section from USGS quad map. PC-based mapping software is acceptable for this purpose.
- site map showing soils distribution, watershed delineation, drainage features, and topography
- site map showing land use (including wetlands), watershed delineation, and drainage features.
- site map showing watershed delineation and principal flow paths for time of concentration determination

All site maps should be to the same scale. In the event that site hydrology is to be changed (e.g., paving, grading, etc), these changes should be described fully and separate site maps should be prepared for pre- and post-development hydrologic configurations.

Aerial photos should be included if they are used to develop the hydrologic model. They should be presented as photocopies to the same scale as the site maps, with watersheds clearly delineated.

Other photos can be included if they contribute to understanding the site hydrology and model development.

Tables should summarize all quantitative information derived from maps, as well as time of concentration calculations and rainfall design event data.

Map data to be listed should include at least the following:

- watershed areas
- land uses, soil types, and curve numbers/rational coefficients by area within watersheds
- land use and soil type total areas.

A separate table summarizing time of concentration calculations should also be included. This table should include all parameters used in the calculations and the method of calculation.

Rainfall design event data can be included in tabular form or as a probability plot. The data source should be identified.

Conceptual Model: The conceptual hydrologic model should be described in enough detail so that understanding the model implementation follows directly. Features in the conceptual model should be related clearly to the physical representation in the previous section. This documentation will consist of narrative, tables, and figures. The narrative should justify the proposed conceptual model for the physical watershed described previously. Significant approximations, assumptions, and weaknesses in the conceptual model should be clearly noted.

Figures should be based on the site map and clearly show model components such as watersheds, channels, and ponds and other storage features. A model process flow chart should also be included, showing all model elements and the manner in which they are connected.

Tables should summarize all model parameters associated with individual model elements.

Model Calibration: The manner in which the model is calibrated should be described. Calibration results should be summarized in tables, as appropriate. Sensitivity to model parameter values should be discussed. It is recognized that in most hydrology studies, calibration data are unavailable. At a minimum, anecdotal information regarding historical experience should be gathered from MDOT maintenance personnel, local officials, and area residents. This information can be used to at least establish the reasonableness of simulation results.

Model Results and Interpretation: A brief narrative of model results should be given. Quantitative results should be communicated primarily by tables and figures. A more fully developed narrative should be devoted to interpretation of the results. This interpretation should clearly identify implications for project design and compliance with MDOT drainage policy.

Appendices: Model input files and spreadsheet files (e.g., Excel) should be supplied on CD-ROM. Input file hard (paper) copy should also be included in the appendices. Additional

information (e.g., large format figures) may also be included if it contributes to the completeness and usefulness of the report.

Submittal, Review and Acceptance: Hydrology studies should be submitted directly to the designated MDOT project contact person. The report should be submitted in paper hardcopy, original software native format (e.g., MS-Word [DOC] file) and Adobe [PDF] digital file formats. Hand-written papers should be scanned and included in the electronic submittal. Large format figures should be submitted as paper copy and Adobe [PDF] files for half-size (11” x 17”) printing. Project contact will forward the report for review as needed. MDOT may contact the engineer or hydrologist for further clarification of hydrology and drainage issues before the report is finally accepted. Consultants are encouraged to contact MDOT Hydrology Section with questions regarding MDOT hydrology practices.

Table 12-2.9: Checklist for Hydrology Reports

Project PIN: ________________
Project Location: ____________

Check	Item	Comments
	Checklist	Completed
	Statement of Supervision	In cover letter
	Executive Summary	
	Introduction	
	Hydrologic Site Description	
	Supporting Documentation	
	Figures for Site Description	8.5x11 or 11x17; to same scale
	Site location	On USGS quad map
	Site map	Soils, watershed bounds, drainage features, topo
	Site map	Land use, watershed bounds, drainage features
	Site map	Watershed bounds, principal flow paths, t_c info
	Aerial photos	If used in analysis; marked appropriately
	Other photos	If informative; annotate or describe
	Tables for Site Description	
	Land uses, soil types, C/RCN by area within watersheds	
	Land use, soil types total areas	
	Time of concentration calcs	
	Model Description	
	Supporting Documentation	
	Figures for Model	Show model components with basic site info
	Tables for Model	Summarize model parameters
	Model Calibration	Sensitivity analysis, anecdotal info
	Results &Interpretation	Identify implications for design & stormwater control
	Appendices	Model input files printout; all computer files on digital media
	Submittal	Paper report; all computer files in native formats and as [PDF] files on CD

12-3 OPEN CHANNELS AND DITCHES

12-3.01 Types

The Department uses the following types of open channels and ditches for drainage:

1) Roadside Ditches: These are used adjacent to and parallel with the highway. They remove the storm runoff from the highway section and drain the subbase material.
2) Median Ditches: These are relatively shallow, depressed areas in medians of multilane, divided highways.
3) Berm Ditches: These are provided longitudinally at the top of a cut to intercept runoff from the hillside.
4) Channels: In general, these refer to naturally occurring pathways for water (e.g., stream channels). Hydraulic design of channels will likely require environmental permitting. Therefore, work in natural channels should always be coordinated with the Environmental Office. The Hydrology and Water Resources Units should be consulted early in the project, before design work begins. Channel design should be executed by a Professional Engineer and/or qualified geomorphologist.

12-3.01 Hydraulic Design

Unless there is a reason to suspect a problem, the designer will not ordinarily perform a hydraulic analysis of ditches. However, channel re-routing should always trigger an analysis. See item (4) above. The following FHWA references may prove useful if detailed analysis and design are required:

Reference: *FHWA Hydraulic Design Series (HDS) # 3*
Design Charts for Open Channel Flow
http://www.fhwa.dot.gov/bridge/hydpub.htm#hds

FHWA Hydraulic Design Series (HDS) #4
Introduction to Highway Hydraulics
http://www.fhwa.dot.gov/bridge/hydpub.htm#hds

12-3.02 Design Criteria

Ditches are employed to provide both stormwater and subbase (shallow ground water) drainage. Ditches and channels will be designed according to the following criteria.

Cross-Section

Chapters 7, 8 and 11 provide the Department's criteria for the shape and dimensions of roadside and median ditches. This includes the front slope, backslope, ditch width and ditch depth. Experience has shown that the standard dimensions generally provide protection against extreme events and therefore ditches are not usually sized explicitly for project-specific water quantity considerations (hydrology and hydraulics). The cross-section of the ditch will be based on the functional classification of the highway and project scope of work. The cross-section of a re-routed channel will be based on hydraulic analysis and geomorphologic considerations. See item (4) above.

Subbase drainage can only be achieved if the ditch is of adequate depth. Occasionally, side ditches cannot be constructed to design standards because the required backslope is too long and will impact abutting property owners. In such cases, a shallow ditch may employed in conjunction with underdrain. The capacity of the shallow ditch should be checked against the design event by hydraulic analysis.

Minimum Gradients

The desirable minimum gradient is 1.0%. The grade should not be less than 0.5%.

Channel/Ditch Lining

While ditches and channels are generally not subject to technical analysis, they should always be reviewed for performance in protecting against erosion and sedimentation (water quality). Designers are referred to the Maine DOT Best Management Practices (BMP) Guide for design guidance. Several FHWA documents provide useful technical back-up to the BMP guide.

References: *Maine DOT Best Management Practices Guide*
http://www.maine.gov/mdot/environmental-office-homepage/surface-water-resources.php

FHWA Hydraulic Engineering Circular (HEC) #11
Design of Riprap Revetment
http://www.fhwa.dot.gov/bridge/hydpub.htm#hec

FHWA Hydraulic Engineering Circular (HEC) #15
Drainage of Roadside Channels with Flexible Linings
http://www.fhwa.dot.gov/bridge/hydpub.htm#hec

12-4 CULVERTS

12-4.01 Physical Characteristics

Culvert Materials

For pipe culverts, there are two options:

1) Option I: Any one of the following may be used:
    a) corrugated steel, metallic (zinc or aluminum) coated pipe;
    b) reinforced concrete pipe; or
    c) any metal pipe allowed under Option III.

2) Option III: Any one of the following may be used:
    a) fiber-bonded corrugated steel pipe;
    b) corrugated aluminum alloy pipe;
    c) polyvinylchloride (PVC) pipe (12 in (300 mm) and 15 in (375 mm) diameters only);
    d) polymer-precoated galvanized corrugated steel pipe; or
    e) reinforced concrete pipe.

The types of culvert material recommended for various site locations are:

1) Reinforced Concrete Pipe (RCP): Use at guardrail locations and other locations at the designer's discretion. Deep fills and high-use roads may be candidates for concrete pipe.
2) Aluminum Alloy Pipe: Use in salt water areas.
3) Flexible Pipe: use where soils are susceptible to settlement. Flexible pipe is everything except reinforced concrete pipe.
4) Option I: use under driveways.
5) Option III: Use unless the criteria in Nos. 1, 2, 3 or 4 apply.

Culvert Shapes

Use circular pipes wherever possible. Pipe arches or elliptical pipes may be used where there are clearance problems, restrictive room for headwater, etc. As discussed in Section 12-1.02, the Bridge Design Division is responsible for the design of all box culverts.

Minimum Size

The minimum sizes of culvert for maintenance purposes are as follows:

1) Driveways. Use minimum 15 in (375 mm) diameter pipe.

2) Cross Culverts. Use minimum 18 in (450 mm) diameter pipe.

Minimum Cover (Design)
Desirably, the pipe will be placed with a cover of at least 2 ft (0.6 m) from the subgrade. The minimum cover for any type of pipe is 1 ft (0.3 m) below the subgrade.

Spacing Between Multiple Pipes
The minimum spacing allowed between multiple pipes is as follows:

1. Up to 36 in (900 mm) pipe: minimum 18 in (450 mm) spacing recommended.
2. 36 in – 72 in (900 mm – 1800 mm) pipe: spacing will be equal to the radius of the larger pipe.
3. Larger than 72 in (1800 mm) pipe: 36 in (900 mm) spacing is recommended.

Minimum Slope
Except where the pipe is used as an equalizer, a minimum slope of 0.5% (0.005 ft/ft) should be used for any type of culvert at any site.

Special Design Considerations
For pipe sizes greater than 48 in (1200 mm), the following should be considered:

1. Foundation. The type of soil at the site may dictate the type of culvert which should be used. For example, in soils susceptible to settlement (e.g., marshes/boggy areas), the culvert may settle more than the area around its entrances. Therefore, the designer should use a flexible pipe or a reinforced concrete pipe with an imperfect trench or similar treatment.

2. Step-Beveled Ends. Where used, step-beveled ends should be well-anchored with a toe wall, or other approved methods, especially at the culvert entrance. Otherwise, an uplift may occur at the opening. This problem may be especially dramatic for metal culverts.

3. Camber: For some culverts under high fills, it may be appropriate to provide a camber for the culvert which would be upbending arc for the culvert gradient. This allows the culvert to attain the desired gradient at the ultimate settlement position. Culvert manufacturer's handbooks and construction manuals provide criteria for the camber technique. Staff geotechnical engineers will assist in determining whether the native soils are susceptible to settlement and will assist in calculating the amount of camber in the culvert.

4. Increased Structural Support. For extremely high fills, certain gages of metal pipe and rigid pipes may need to be center strutted and fitted with compressible wooden caps. This would be necessary during the placement of the fill, and the increased support would be removed after placement. Concrete pipe should also be considered in cases of deep fill.

5. Allowable Headwater. Highway culverts should ordinarily be designed to a nominal headwater-to-diameter ratio (H_w/D) of 1.5 for the 50-year design flow. The actual design ratio will usually be something smaller or larger than 1.5 (but no larger than 2) since pipes come in incremental sizes. The overriding concern should be to keep the design event below the base and subbase. In cases of shallow cover, this may result in (H_w/D) values less than 1.5.

Wall Thicknesses

The following tables present the Department's criteria for the minimum wall thicknesses of pipe culverts:

Table 12-4.1 "Circular Culvert Pipes"
Table 12-4.2 "Pipe Arch Culverts"
Table 12-4.3 "Coupling Band Width Requirements", and
Table 12-4.4 "Types B & C Underdrain Pipes"

Table 12-4.1
CIRCULAR CULVERT PIPES – WALL THICKNESSES

	Nominal Pipe Wall Thickness in (in)							
	Corrugated Metal				Plastic	Reinforced Concrete		
	Option I		Option I/III		Option III	Option I/III		
Diameter (in)	M 218	M 274	M-246 & Fiber Bonded	M 197	M 278	M 170 Class III Wall A	M 170 Class III Wall B	M 170 Class III Wall C
12	0.079	0.064	0.064	0.075	0.358	1 ¾	2	
15	0.079	0.064	0.064	0.075	0.438	1 7/8	2 ¼	
18	0.109	0.079	0.079	0.075		2	2 ½	
21	0.109	0.079	0.079	0.075		2 ¼	2 ¾	
24	0.109	0.079	0.079	0.075		2 ½	3	3 ¾
27	0.109	0.079	0.079	0.105		2 5/8	3 ¼	4
30	0.109	0.079	0.079	0.105		2 ¾	3 ½	4 ¼
33	0.109	0.079	0.079	0.105		2 7/8	3 ¼	4 ½
36	0.109	0.079	0.079			3	4	4 ¾
36 (1)			0.079	0.75				
42	0.138		0.109			3 ½	4 ½	5 ¼
42 (1)		0.109	0.079	0.105				
48	0.138		0.109			4	5	5 ¾
48 (1)		0.109	0.079	0.105				
54	0.168		0.138			4 ½	5 ½	6 ¼
54 (1)		0.138	0.079	0.105				
60	0.168		0.138			5	6	6 ¾
60 (1)		0.138	0.079	0.105				
66 (1)			0.079	0.135		5 ½	6 ½	7 ¼
72 (1)			0.109	0.135		6	7	7 ¾
78 (1)			0.109	0.164			7 ½	8 ¼
84 (1)			0.109	0.164			8	8 ¾

Metal Pipe values are for 2 2/3” x ½” corrugations unless diameter is followed by (1), which requires 3 in x 1 in corrugations for aluminum pipes and 3” x 1” or 5” x 1” corrugations for steel pipes; corrugations in (in).

Option I pipes shall only be used for entrances. Fill heights over 15 ft (4.5 m) may require larger metal gages.

M 170 = Reinforced Concrete Pipe
M 278 = Polyvinyl Chloride Pipe
M 197 = Corrugated Aluminum Alloy Pipe
Fiber Bonded = MDPT Spec. 707.04
M 218 = Zinc-coated (galvanized) corrugated steel pipe
M 274 = Aluminum-coated (Type 2) corrugated steel pipe
M 246 = Polymer precoated galvanized corrugated steel pipe

Table 12-4.2
PIPE ARCH CULVERTS – WALL THICKNESSES

Nominal Wall Thickness in (in)		
	Corrugated Metal Pipe Arch Option III	
Nominal Size in (in Span x Rise	**M 246 & Fiber Bonded**	**M 197**
21 x 15	0.079	0.075
24 x 18	0.079	0.075
28 x 20	0.079	0.105
35 x 24	0.109	0.105
40 x 31 (1)	0.079	0.075
42 x 29 (2)	0.109	
46 x 36 (1)	0.079	0.105
49 x 33 (2)	0.138	
53 x 41 (1)	0.079	0.105
57 x 38 (2)	0.138	
60 x 46 (1)	0.109	0.135
64 x 43 (2)	0.168	
66 x 51 (1)	0.109	0.135
73 x 55 (1)	0.109	0.164
81 x 59 (1)	0.109	0.164

Coated Steel Pipe Equivalents (in)
18 gage = 0.052
16 gage = 0.064
14 gage = 0.079
12 gage = 0.109
10 gage = 0.138
8 gage = 0.168
Aluminum Pipe Equivalents (in)
18 gage = 0.048
16 gage = 0.06
14 gage = 0.075
12 gage = 0.105
10 gage = 0.135
8 gage = 0.164

Metal pipe values are for 2 2/3” x ½” corrugations unless size is followed by a (1), which denotes 3” x 1” corrugations.

M 246 = Polymer pre-coated galvanized corrugated steel pipe
M 197 = Corrugated Aluminum Alloy Pipe
Fiber Bonded = MDOT Spec. 707.04

Minimum Cover is 3 Feet (1 m)
(2) = Either size is acceptable

Table 12-4.3
COUPLING BAND WIDTH REQUIREMENTS

Nominal Corrugation (in)	Nominal Pipe Inside Diameter	Coupling Band Width (in)			
		Annular Corrugated Bands		Helically Corrugated Bands	
		M 196	M 36	M 196	M 36
1 ½ x ¼	6	10 ½	10 ½	7	7
2 2/3 x ½	12 – 84	10 ½	10 ½		
3 x 1	30 - 84	12	12		
5 x 1	36 x 84		20		

Helically corrugated pipe 12” diameter and larger shall have the ends rerolled to provide at least two annular corrugations.

Pipe with spiral corrugations shall have continuous helical lock seams.

M 196 = Corrugated Aluminum Alloy Pipe
M 36 = Corrugated Steel Pipe

Table 12-4.4
TYPES B & C UNDERDRAIN PIPE

Metal Pipe				Plastic Pipe Stiffness @ 5% Deflection			
Nominal Wall Thickness (in)				PVC Pipe		Polyethylene Pipe	
Diameter	M 218	M 274 M 246	M 197	M 278	ASTM F 949	M 294 SP Dual-Wall Unanchored	M 252 SP Dual-Wall Unanchored
Type “B” 6	0.064	0.052	0.048	46	50		60
Type “C” 12	0.079	0.064	0.075	46		50	
15	0.079	0.064	0.075	46		42	
18	0.079	0.064	0.075			40	
21	0.079	0.064	0.075				
24	0.079	0.064	0.075			40	
30	0.109	0.079	0.105				
36	0.109	0.079	0.105				

12-4.02 Maximum Cover/Height of Fill

The maximum allowable cover (or height of fill) over a culvert will depend on several factors, including the size of the culvert, its material and shape, and the type of bedding it is placed on. The following presents the Department's criteria for various culvert types.

Reinforced Concrete Pipe

The following procedure has been developed to assist the designer in determining the type of installation and class of pipe for the fill height encountered at any particular culvert location using a Class "C" bedding. It is intended that the designer consider the culvert strength design in the following order of construction procedures:

1. Positive projecting conduit
2. Zero projecting conduit
3. Negative projecting conduit or imperfect (induced) trench

Positive Projecting Conduit

This method assumes that the conduit is installed in the specified bedding with the top of the conduit projecting above the surface of the natural ground or compacted fill, at the time of installation, and then covered with earth fill. The use of this method by installation of field personnel will be assumed unless another method is specified. The maximum allowable fill heights for this method are shown in Table 12-4.5.

TABLE 12-4.5
MAXIMUM ALLOWABLE HEIGHT OF FILL IN FEET
(Positive Projecting Conduit)

Pipe Diameter (in)	Class III	Class IV	Class V
12	11.40	16.83	21.01
15	11.71	17.28	21.57
18	11.94	17.61	21.97
24	12.25	18.04	22.50
30	12.46	18.33	22.85
36	12.62	18.55	23.11
42	12.75	18.72	23.31
48	12.86	18.86	23.47
54	12.96	18.98	23.61
60	13.05	19.09	23.73
66	13.13	19.18	23.84
72	13.21	19.27	23.94

Note: These fill heights have been derived assuming a soil weight of 125 lbs per cubic foot and a safety factor of 1.5 times the ultimate pipe strength.

Zero Projecting Conduit

This method assumes that the conduit is installed, with the specified bedding, in shallow trenches of such depth that the top of the conduit is even with the surface of the natural ground or compacted fill and then covered with and embankment which extends above this ground level. The maximum allowable fill heights for this method are shown in Table 12-4.6. It should be noted that the trench width used in the development of this table was the culvert outside diameter plus 30 in (750 mm).

TABLE 12-4.6
MAXIMUM ALLOWABLE HEIGHT OF FILL IN FEET
(Zero Projecting Conduit)

Pipe Diameter (in)	Class III	Class IV	Class V
12	15.66	23.16	28.93
15	16.08	23.77	29.68
18	16.37	24.20	30.22
24	16.77	24.77	30.92
30	17.03	25.14	31.38
36	17.22	25.40	31.70
42	17.37	25.61	31.94
48	17.50	25.77	32.13
54	17.60	25.90	32.29
60	17.69	26.02	32.43
66	17.77	26.12	32.55
72	17.84	26.21	32.65

Note: These fill heights have been derived assuming a soil weight of 125 lbs per cubic foot and a safety factor of 1.5 times the ultimate pipe strength.

Negative Projecting Conduit of Imperfect Trench

This method assumed that the conduit is installed, with the specified bedding, in shallow trenches of such depth that the top of the conduit is below the surface of the natural ground or compacted fill and then covered with an embankment which extends above this ground level.

The imperfect (induced) trench method assumes that the conduit is installed in the same manner as a positive projecting conduit with the desired class of bedding. After the embankment has been constructed to some predetermined elevation, a trench is excavated in the compacted fill directly over the pipe, the trench backfilled with highly compressible material and the balance of the fill completed by normal construction methods.

When the conduits are encountered with fill heights in excess of the maximums shown in Tables 12-4.7 and 12-4.8, they will be designed on an individual basis using the procedures shown in “Loads and Supporting Strengths for Precast Concrete Pipe”, a copy of which is available from the Design Engineer. Both of the above methods will be considered and a cost comparison

made. It should be noted that a minimum soil density of 125 lbs/ft^3 (= 2000 kg/m^3 = 2 g/cm^3) should be used and a minimum safety factor of 1.5 times the ultimate strength must be attained.

Corrugated Metal Pipe

Table 12-4.7 presents the maximum heights of fill for the following corrugated metal pipes:

1. corrugations of 2-2/3 in x ½ in (67.8 mm x 6.4 mm)
2. smoothlined corrugations

TABLE 12-4.7
MAXIMUM HEIGHTS OF FILL (Corrugated Metal Pipe)

Pipe Diameter (in)	Standard Thick (in)/ Height of Fill (ft)	Non-Standard Thick. /Height of Fill	Non-Standard Thick. /Height of Fill	Non-Standard Thick. /Height of Fill
12 & 15	0.064/1.5 – 45			
18	0.064/1.5 – 35	0.079/35 – 55		
21	0.064/1.5 – 35	0.079/35 – 50	0.109/50 – 55	
24	0.064/1.5 – 20	0.079/20 – 40	0.109/40 – 50	0.138/50 – 60
30	0.079/1.5 – 25	0.109/25 – 40	0.138/25 – 45	0.168/55 – 60
36	0.079/1.5 – 15	0.109/15 – 25	0.138/25 – 45	0.168/45 – 60
42	0.109/1.5 – 20	0.138/20 – 35	0.168/35 – 60	
48	0.109/1.5 – 25	0.138/20 – 50	0.168/50 – 60	
54	0.109/1.5 – 20	0.138/20 – 40	0.168/40 – 50	
60	0.138/1.5 – 25	0.168/25 – 45		
66	0.138/1.5 – 20	0.168/20 – 40		
72	0.168/1.5 – 30			

Notes:

1) This table applies to metal pipe with smoothlined corrugations and 2 2/3” x ½” corrugations.
2) Shop strut for pipe diameters of 48”and larger.

Corrugated Steel Pipe Arches

Table 12-4.8 presents the maximum heights of fill for steel pipe arches with corrugations of 2-2/3 in x ½ in (67.8 mm x 6.4 mm).

TABLE 12-4.8
MAXIMUM HEIGHTS OF FILL - CORRUGATED STEEL PIPE ARCHES
(Corrugations of 2 2/3" x ½")

Equivalent Pipe Diameter (in.)	Span (in.)	Rise (in.)	Height of Fill Above Top of Arch			
			18"-3'	4'-5'	6'-10'	11'-15'
			Wall Thickness (in.)			
15	18	11	.060	.060	.060	.060
18	22	13	.060	.060	.060	.060
24	29	18	.075	.075	.075	.075
30	36	22	.075	.075	.075	.075
36	43	27	.105	.105	.105	.105
42	50	31	.105	.105	.105	.105
48	58	36	.135	.105	.105	.135
54	65	40	.135	.135	.135	.164
60	72	44	.164	.164	.164	

Note: minimum cover is 18 in (450 mm).

Structural Steel Plate

Table 12-4.9 presents the maximum heights of fill for structural plate steel circular pipes with corrugations of 6 in x 2 in (150 mm x 50 mm). Table 12-4.10 presents the maximum heights of fill for structural fill for structural plate steel pipe arches with corrugations of 6 in x 2 in. Table 12-4.11 presents the maximum heights of fill for structural plate steel arches with corrugations of 6 in x 2 in.

Table 12-4.9
STRUCTURAL PLATE STEEL CIRCULAR PIPE

(corrugations of 6” x 2”)

			Height of Fill Above Steel Pipe (ft)																	
Dia	Area	Min	Min	5	10	15	20	25	30	35	40	45	50	55	60	70	80	90	100	110
(ft)	(ft^2)	Fill (ft)	5	10	15	20	25	30	35	40	45	50	55	60	70	80	90	100	110	120
60	20.6	1.5	0.11	0.11	0.11	0.11	0.11	0.11	0.14	0.14	0.14	0.14	0.17	0.17	0.19	0.22	0.22	0.25	0.28	•
66	23.8	1.5	0.11	0.11	0.11	0.11	0.11	0.14	0.14	0.14	0.14	0.14	0.17	0.19	0.19	0.22	0.25	0.28	•	•
72	28.3	1.5	0.11	0.11	0.11	0.11	0.11	0.14	0.14	0.14	0.17	0.17	0.19	0.19	0.22	0.25	0.25	0.28	•	♦
78	33.2	1.5	0.11	0.11	0.11	0.11	0.11	0.14	0.14	0.17	0.17	0.19	0.19	0.22	0.25	0.25	0.28	•	•	♦
84	38.5	1.5	0.11	0.11	0.11	0.11	0.14	0.14	0.14	0.17	0.17	0.19	0.19	0.22	0.25	0.28	•	•	♦	
90	44.2	1.5	0.14	0.14	0.14	0.14	0.17	0.14	0.17	0.17	0.17	0.19	0.22	0.22	0.25	0.28	•	♦	♦	
96	50.3	1.5	0.14	0.14	0.14	0.14	0.17	0.17	0.17	0.17	0.19	0.22	0.22	0.25	0.28	•	•	♦		
102	56.7	2	0.14	0.14	0.14	0.14	0.17	0.17	0.17	0.19	0.19	0.22	0.25	0.25	0.28	•	♦	♦		
108	63.6	2	0.14	0.14	0.14	0.14	0.17	0.17	0.17	0.19	0.22	0.22	0.25	0.28	•	•	♦			
114	70.9	2	0.14	0.14	0.14	0.14	0.19	0.17	0.19	0.19	0.22	0.22	0.25	0.28	•	♦	♦			
120	78.5	2	0.14	0.14	0.14	0.14	0.19	0.17	0.19	0.22	0.22	0.25	0.28	•	•	♦				
126	86.6	2	0.14	0.14	0.14	0.14	0.19	0.17	0.19	0.22	0.22	0.25	0.28	•	•	♦				
132	95.0	2	0.17	0.14	0.14	0.14	0.19	0.19	0.22	0.22	0.25	0.28	•	•	♦	♦				
138	103.9	2	0.17	0.14	0.14	0.17	0.19	0.19	0.22	0.22	0.25	0.28	•	•	♦					
144	113.1	2	0.17	0.17	0.17	0.17	0.19	0.19	0.22	0.25	0.25	0.28	•	•	♦					
150	122.7	2	0.17	0.17	0.17	0.17	0.19	0.19	0.22	0.25	0.28	•	•	♦						
156	132.7	2	0.17	0.17	0.17	0.17	0.19	0.22	0.25	0.25	0.28	•	•	♦						
162	143.1	2	0.19	0.17	0.17	0.17	0.19	0.22	0.25	0.25	0.28	•	♦	♦						
168	153.9	2	0.19	0.17	0.17	0.19	0.19	0.22	0.25	0.28	•	•	♦	♦						
174	165.1	2	0.19	0.19	0.19	0.19	0.22	0.22	0.25	0.28	•	♦	♦							
180	176.7	2	0.19	0.19	0.19	0.22	0.22	0.25	0.25	0.28	•	♦	♦							

• 0.28 in thick; 6 bolts per 1 ft long seam

♦ 0.28 in thick; 8 bolts per 1 ft long seam

All other thicknesses:
4 bolts per 1 ft long seam

Notes: As design requires for added resistance to abrasion and/or corrosion, use next heavier thickness (maximum 0.28 in) for bottom plates.
All structural plate pipes must be 5% elliptical.
4- and 6-plate pipes should have 1 bottom plate; 8- and 10-plate pipes should have 3 bottom plates.

Table 12-4.10
STEEL STRUCTURAL PLATE PIPE ARCHES
(Corrugations of 6” x 2”)

Span (ft-in)	Rise (ft-in)	Area (ft^2)	Corner Plate Radius (in)	Min Fill ft-in	Height of Fill Above Top of Pipe Arches (ft)											
					2	3	4	5-7	8	9	10	11	12	13	14	15
					For Steel Thickness (Inches)											
6-1	4-7	22	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
6-4	4-9	24	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
6-9	4-11	26	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
7-0	5-1	28	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
7-3	5-3	31	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138	0.138
7-8	5-5	33	18	2-0	0.138	0.138	0.138	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138	0.138
7-11	5-7	35	18	2-0	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
8-2	5-9	38	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
8-7	5-11	40	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
8-10	6-1	43	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
9-4	6-3	46	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
9-6	6-5	49	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
9-9	6-7	52	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.168
10-3	6-9	55	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.168	0.168
10-8	6-11	58	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.168	0.168	0.168
10-11	7-1	61	18	2-6		0.168	0.168	0.138	0.138	0.138	0.138	0.138	0.138	0.168	0.168	0.188
11-5	7-3	64	18	2-6		0.168	0.168	0.168	0.138	0.138	0.138	0.138	0.168	0.168	0.168	0.188
11-7	7-5	67	18	2-6		0.168	0.168	0.168	0.138	0.138	0.138	0.138	0.168	0.168	0.188	0.188
11-10	7-7	71	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188
12-4	7-9	74	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188
12-6	7-11	78	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188
12-8	8-1	81	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188	
12-10	8-4	85	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188	0.188	0.188	
13-5	8-5	89	18	2-6		0.188	0.168	0.168	0.168	0.168	0.168	0.188	0.188	0.188	0.188	
13-11	8-7	93	18	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188		
14-1	8-9	97	18	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188		
14-3	8-11	101	18	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.218			
14-10	9-1	105	18	2-6		0.188	0.188	0.188	0.188	0.188	0.218	0.218	0.218			
15-4	9-3	109	18	2-6		0.218	0.188	0.188	0.188	0.188	0.218	0.218	0.218			**USE**
15-6	9-5	113	18	2-6		0.218	0.218	0.188	0.188	0.188	0.218	0.218				
15-8	9-7	118	18	2-6		0.218	0.218	0.188	0.188	0.188	0.218	0.218				**31 in RADIUS**
15-10	9-10	122	18	2-6		0.218	0.218	0.188	0.188	0.188	0.218	0.218				
16-5	9-11	126	18	2-6		0.218	0.218	0.218	0.218	0.218	0.218					**STRUCTURES**
16-7	10-1	131	18	2-6		0.218	0.218	0.218	0.218	0.218	0.218					
13-3	9-4	98	31	2-6		0.188	0.168	0.168	0.168	0.168	0.168	0.188	0.188	0.188	0.188	0.188
13-6	9-6	102	31	2-6		0.188	0.168	0.168	0.168	0.168	0.168	0.188	0.188	0.188	0.188	0.188
14-0	9-8	106	31	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
14-2	9-10	110	31	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
14-5	10-0	115	31	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.218	0.218
14-11	10-2	119	31	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.218	0.218
15-4	10-4	124	31	2-6		0.218	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.218	0.218	0.218
15-7	10-6	129	31	2-6		0.218	0.218	0.188	0.188	0.188	0.188	0.188	0.188	0.218	0.218	0.218
15-10	10-8	133	31	2-6		0.218	0.218	0.188	0.188	0.188	0.188	0.188	0.218	0.218	0.218	0.218
16-3	10-10	138	31	2-6		0.218	0.218	0.218	0.188	0.188	0.188	0.188	0.218	0.218	0.218	0.218
16-6	11-0	143	31	2-6		0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	
17-0	11-2	148	31	3-6			0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	
17-2	11-4	153	31	3-6			0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	
17-5	11-6	158	31	3-6			0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218		
17-11	11-8	163	31	3-6			0.218	0.218	0.218	0.218	0.218	0.218	0.249	0.249		
18-1	11-10	168	31	3-6			0.218	0.218	0.218	0.218	0.218	0.249	0.249	0.249		
18-7	12-0	174	31	3-6			0.218	0.218	0.218	0.218	0.218	0.249	0.249	0.249		
18-9	12-2	179	31	3-6			0.218	0.218	0.218	0.218	0.249	0.249	0.249			
19-3	12-4	185	31	3-6			0.218	0.218	0.218	0.218	0.249	0.249	0.249			
19-6	12-6	190	31	3-6			0.218	0.249	0.249	0.249	0.249	0.249	0.249			
19-8	12-8	196	31	3-6			0.218	0.249	0.249	0.249	0.249	0.249				
19-11	12-10	202	31	3-6			0.218	0.249	0.249	0.249	0.249	0.249				
20-5	13-0	208	31	3-6			0.249	0.249	0.249	0.249	0.249	0.249				
20-7	13-2	214	31	3-6			0.249	0.249	0.249	0.249	0.249	0.249				

Note: for abrasion/corrosion resistance, use next heavier thickness (max. .280” thickness) for bottom and corner plates.

Table 12-4.11
FILL HEIGHT for STEEL STRUCTURAL PLATE ARCHES
(Corrugations of 6” x 2”)

Span (ft)	Min Cover (in)	Height of Fill Above Top of Steel Structural Plate Arch (ft)								
		2	3	4	5	6	7	8	9	10
		For Steel Thickness (in)								
4-10	24						0.109	0.109	0.109	0.109
11	24	0.138	0.138	0.109	0.109		0.109	0.109	0.109	0.109
12	24	0.138	0.138	0.109	0.109		0.109	0.109	0.138	0.138
13	24	0.168	0.138	0.109	0.109		0.109	0.138	0.138	0.168
14	24	0.168	0.168	0.138	0.138		0.138	0.168	0.168	0.168
15	24	0.188	0.168	0.138	0.138		0.138	0.168	0.168	0.188
16	24	0.218	0.188	0.168	0.168		0.168	0.188	0.188	0.218
17	24	0.218	0.218	0.188	0.168	0.168	0.168	0.188	0.218	0.249
18	24	0.249	0.218	0.188	0.188	0.168	0.188	0.218	0.249	0.249
19	24	0.280*	0.249	0.218	0.218	0.188	0.218	0.249	0.249	0.280
20	24	0.280*	0.280*	0.249	0.218	0.218	0.218	0.249	0.280	
21	24		0.280*	0.249	0.249	0.218	0.249	0.280		
22	24			0.280	0.249	0.249	0.249	0.280		
23	24				0.280	0.249	0.280			
24	24					0.280	0.280			
25	24					0.280				

Note: * Not to be used when rise to span ratio is 0.3 or less.

Corrugated Aluminum

Table 12-3.12 presents the maximum heights of fill for corrugated aluminum alloy circular pipe culverts. Table 12-3.13 presents the maximum heights of fill for corrugated aluminum pipe arches.

Table 12-4.12
FILL HEIGHT for ALUMINUM ALLOY CORRUGATED CULVERT

Culvert Diameter (Inches)	Type of Shape	Minimum (a) Recommended Cover (Inches)	Maximum Height of Fill (ft) for Pipe Thickness (in)				
			.060	.075	.105	.135	.164
12	Full Circle	8	35	40	50		
15	Full Circle	8	32	35	40		
18	Full Circle	8	26	30	35		
21	Full Circle	9	21	25	30		
24	Full Circle	9	13	21	30		
30	Full Circle	9		19	25	30	
	5% Vertically Elongated	9		24	30	35	
36	Full Circle	10		10	18	25	30
	5% Vertically Elongated	10			21	30	35
42	Full Circle	12			16	20	25
	5% Vertically Elongated	12			20	25	30
	5% Field Strutted (b)	12			30	35	40
48	Full Circle	15			15	20	25
	5% Vertically Elongated	15			18	25	30
	5% Field Strutted (b)	15			30	35	40
54	Full Circle	15			15	20	25
	5% Vertically Elongated	15			18	22	30
	5% Field Strutted (b)	15			25	30	35
60	Full Circle	18				14	18
	5% Vertically Elongated	18				17	25
	5% Field Strutted (b)	18				25	30
66	Full Circle	21				13	17
	5% Vertically Elongated	21				15	20
	5% Field Strutted (b)	21				25	30
72	Full Circle	24				12	15
	5% Field Strutted (b)	24				20	25
78	5% Field Strutted (b)	24				16	20
84	5% Field Strutted (b)	24					15
96	5% Field Strutted (b)	24					10

(a) For the special case of heavy construction wheeled vehicles, use 2 feet cover to 36” diameter and 2/3 of the diameter at greater than 36” diameter.
(b) Field strutting is defined as shaping pipe elliptically by wire or timber strutting or careful, thorough compaction of backfill around pipe during installation.

The following apply: Loading: AASHTO – H2O Highway Shape: 2 2/3” x ½”
Table values are for 85% or greater compaction.

Table 12-4.13
COVER HEIGHT for CORRUGATED ALUMINUM PIPE ARCHES
(Corrugations of 2 2/3" x ½")

Arch Span and Rise (in) (Helical or Annular)	Minimum and Maximum Height of Cover, in feet, For Various Metal Thicknesses (in)				
	.060	.075	.105	.135	.165
17 x 13	1-15				
21 x 15	1-15				
24 x 18	1-14	1-16			
28 x 20		1-14			
35 x 24		1-13	1-16		
42 x 29			1 ¼-13	1 ¼-16	
49 x 33			1 ¼-12	1 ¼-16	
57 x 38			1 ¼-9	1 ¼-12	
64 x 43				1 ¼-11	1 ½-14
71 x 47				2-9	2-11
77 x 52				3-9	2-10
83 x 57					2-10

12-4.03 Hydraulic Design of Culverts

A complete treatment of hydraulic design of culverts is beyond the scope of the manual. General guidelines are given, as well as methods for design of simple projecting culverts under inlet control. It is recommended that designers limit their work to cross-pipes that convey only storm water. Perennial streams, outlet control, sophisticated inlet treatments for improved efficiency, and fish passage should be referred to hydraulic engineering staff.

Basic Design Controls
Certain criteria will control the hydraulic design of culverts:

1. Allowable Headwater (Design Storm). For inlet control, the headwater depth above inlet at the upstream end of the culvert should be 1.5 (desirable) times the diameter of the culvert ($H_w/D = 1.5$) during the design discharge. The actual ratio may be somewhat smaller or larger (up to a maximum of 2), since pipes come in incremental sizes and the exact size needed to deliver $H_w/D = 1.5$ may not be available. Headwater at the inlet should not rise above the subgrade during the design discharge. In addition, the designer should consider:

   a. Existing and future land use in the watershed
   b. Impacts on the surrounding land

c. Potential pavement damage when the water rises above the subbase elevation
d. 100-year flood requirements of the Federal Emergency Management Agency (FEMA). When the 100-year flood stage is above the culvert outlet, design should be referred to an experienced hydraulic engineer.
e. debris
f. the need to create lower-than-existing headwater ponding in the flood-prone or sensitive areas upstream from the culvert.

2. <u>Allowable Headwater (Check Storm)</u>. For both inlet and outlet control, the water level at the inlet should not be higher than the edge of the shoulder berm.

3. <u>Perennial Streams and Outlet to Adjacent Streams</u>. Flood stage in adjacent streams and perennial streams crossing under roads will back water up through the culvert. Each cross-pipe should be identified as to whether or not it passes a perennial stream or outlets to an adjacent perennial stream. Design should be referred to experienced hydraulic engineers so that flood stage tailwater conditions can be properly accounted for.

4. <u>Multiple Pipes</u>. The design discharge is assumed evenly divided in each barrel.

5. <u>Maximum Outlet Velocity</u>. Where high outlet velocities are unavoidable because of steep slopes, erosion control measures and/or energy dissipators should be considered at the downstream end of the culvert.

6. <u>Fish Passage</u>: The designer should confirm with the Environmental Office whether the culvert must be designed for fish passage. If fish passage is an issue, the designer should consult with the Environmental Office for further guidance.

7. <u>Reference</u>. The designer is encouraged to review the following Federal Highway Administration (FHWA) references for a more complete discussion of hydrology and hydraulic design of culverts:

   HDS # 2 (Highway Hydrology)
   HDS # 5 (Hydraulic Design of Highway Culverts)
   HEC #14 (Energy Dissipators for Culverts and Channels)

These documents are available as hard copy, on the FHWA web page, and on CD-ROM distributed by FHWA.

8. <u>Microcomputer Programs</u>. Readily available public domain (HY8 from Federal Highway Administration, available from FHWA and MDOT web pages) and proprietary software (e.g., CulvertMaster by Haested Methods, Waterbury, Connecticut) may be used culvert analysis.

Types of Culvert Flow

There are two major types of culvert flow:

Inlet Control: Inlet control occurs when the discharge through the culvert is controlled by inlet conditions: the pipe itself is capable of passing more water than the inlet. This occurs when the culvert is on a steep slope or when there is too much constriction of the flood plain. Critical depth occurs at the inlet and the flow in the culvert is mostly supercritical. The pipe inlet is modeled as an orifice when inlet control prevails. A useful indication of inlet control is free outlet flow with little or no tailwater. Outlet conditions (including tailwater) and culvert barrel roughness and length are not factors in determining culvert capacity.

Outlet Control: Outlet control occurs when the discharge through the culvert is controlled by outlet or pipe conditions. The flow in an outlet control culvert may be subcritical, full, or pressure flow. In outlet control, the hydraulic and geometric characteristics of the culvert (type, slope, length, roughness "n", etc) and the tailwater elevation play an important role in determining the discharge capacity of the culvert. When a culvert conveys a perennial stream or discharges to an adjacent stream, tailwater effects in the culvert are likely under peak flow conditions. Design for tailwater (outlet control) is beyond the scope of this manual.

Design Procedure

This manual is limited to stormwater culverts under inlet control; perennial streams and tailwater are beyond the scope of this manual. However, the simple methods presented here are useful for developing preliminary estimates for these more complicated situations.

Headwall inlets will give the smallest H_w/D for a given flow, while mitred inlets give ratios between headwall and simple projecting treatments. Routine design should be limited to simple projecting inlets; other inlet treatments should be referred to hydraulic engineering staff.

Culverts under inlet control and with fully submerged inlets function hydraulically as orifices. The equation for simple orifice flow and adapted for culverts is

$$Q = C_d A\{2g(H_w - 0.5D)\}^{0.5}$$

where C_d is the dimensionless discharge coefficient (usually 0.6; can range between 0.5 and 1) and g is acceleration due to gravity (32.2 ft/s^2 = 9.81 m/s^2). Combining coefficients and solving for the headwater-diameter ratio gives

$$H_w/D = c\{Q/AD^{0.5}\}^2 + Y$$

where $c = 1/(2gC_d^2)$ and $Y = 0.5$.

The value $Y = 0.5$ is for a simple generic orifice. Empirical results yield other Y values for real culverts operating under inlet control.

Pipes are sized to achieve a specified (H_w/D) value. Larger allowable (H_w/D) creates more flow capacity in a pipe of given size. For a specified (H_w/D) ratio and circular flow area, pipe size D is calculated as

$$D = \{[\{H_w/D - Y\}/c]^{-0.5} 4Q/\pi\}^{0.4} = a_c Q^{0.4}$$

where $a_c = \{4[\{H_w/D - Y\}/c]^{-0.5}/\pi\}^{0.4}$.

Table 12-4.14 shows orifice equation coefficients for commonly used culvert inlet treatments. The simple projecting inlet is probably used most often in highway stormwater cross-pipe applications. Headwall inlets are generally discouraged because the massive concrete structure presents a potentially dangerous obstacle to motorists. Mitred inlets may be employed on larger perennial streams but typically are not used for smaller stormwater flows.

Table 12-4.14
Orifice Equations for CMP Culvert under Inlet Control

	Coefficient					
	C_d	c		Y	a_c ($H_w/D = 1.5$)	
Inlet Type		U.S.	metric		U.S.	metric
Projecting	0.53	0.055	0.181	0.54	0.622	0.789
Mitred	0.58	0.046	0.152	0.75	0.631	0.800
Headwall	0.64	0.038	0.124	0.69	0.597	0.757
Generic	0.60	0.043	0.142	0.50	0.587	0.745
$Q = C_d A\{2g(H_w - 0.5D)\}^{0.5}$ $H_w/D = c\{Q/AD^{0.5}\}^2 + Y$ $c = 1/(2gC_d^2)$						

Table 12-4.15 shows the size equation coefficients for circular CMP culvert and different H_w/D values. While culverts are generally sized to $H_w/D = 1.5$, H_w/D as large as 2 may be permissible under high fills where the high water can be kept out of the subbase. Also, strict design for $H_w/D < 1.5$ may occasionally lead to using pipes larger than necessary. Using a smaller pipe may give H_w/D just slightly larger than 1.5, or in the acceptable rang of 1.5 to 2.

Culvert size can also be checked against just-full ($H_w/D = 1$) open-channel Manning's Equation flow. For circular pipes Manning's Equation is

$$Q = Av = (\pi D^2/4)\{\lambda R_h^{2/3} S^{1/2}/n\} = (\pi D^2/4)\{\lambda (D/4)^{2/3} S^{1/2}/n\}$$
$$D = \{4^{5/3} n/\lambda\pi S^{1/2}\}^{3/8} Q^{3/8} = a_M Q^{0.375}$$

where $a_M = \{4^{5/3} n/\lambda\pi S^{1/2}\}^{3/8}$
λ = Manning unit conversion factor (1.486 for US Customary; 1 for metric).

Table 12-4.15
Coefficients for CMP Culvert Sizing Functions

Inlet Control Equation			Manning's Equation		
H_w/D	a_C		S	a_M	
	U.S.	metric		U.S.	metric
1.0	0.721	0.914	0.001	1.222	1.418
1.5	0.622	0.789	0.005	0.904	1.049
2.0	0.572	0.726	0.010	0.794	0.921
2.5	0.540	0.684	0.020	0.697	0.809
3.0	0.516	0.654	0.050	0.587	0.681
$D = a_c Q^{0.4}$			$D = a_M Q^{0.375}$		
Notes: values are for simple projecting, non-embedded, circular CMP culvert, n = 0.025 Inlet control (slope correction not included) Manning's Equation just-full free-surface (non-pressurized) flow					

These equations for pipe size D are graphed in Figure 12-4.1; the "diameter" axis is in standard pipe size increments of 6 in (150 mm). For specified Q and (H_w/D) values, one simply looks up the appropriate pipe size. The final design size should be rounded to the next available size that offers the best compromise between cost, performance, and physical configuration, H_w/D preferably less than 1.5 and nevcr exceeding $H_w/D = 2$. The actual (H_w/D) value for the chosen size should be included in the design report.

The basic steps for designing simple circular culverts are:

1) Select the design frequency return period T, ordinarily 50 years.
2) Determine the design discharge Q_T, using hydrologic methods presented elsewhere in this manual.
3) Size the culvert using the equations above or look up on chart. Report the actual H_w/D for the final size.

Comprehensive culvert design should be performed using FHWA computer program HY8 or equivalent. Routine design for highway projects should be limited to simple projecting, circular CMP culverts. Other shapes, inlet types, and sophisticated treatments for improved inlet efficiencies, and all pipes D = 10 ft (3 m) and larger, should be referred to staff experienced in hydraulics and culvert design. Routine design can be performed using the equations and charts in this manual, as well as accompanying spreadsheet tools.

Example: Peak flow Q_{50} has been estimated to be 66 ft^3/s (1.87 m^3/s). Assuming a simple projecting inlet under inlet control, size the culvert.

Standard policy is to design for $H_w/D = 1.5$, with H_w/D as large as 2 acceptable provided high water is below the subbase. By calculation,

$$D = a_c Q^{0.4} = 0.622(66)^{0.4} = 3.32 \text{ ft} = 1.01 \text{ m}$$
$$= 40 \text{ in} = 1010 \text{ mm for } H_w/D = 1.5$$

In order to maintain $H_w/D \leq 1.5$, the next standard pipe size (D = 42 in or 1050 mm; A = 9.62 ft^2 = 0.866 m^2) should be used. The next lower pipe size (D = 36 in = 900 mm; A = 7.07 ft^2 = 0.636 m^2) should be checked to see what the actual H_w/D would be with the smaller pipe. The smaller pipe may be acceptable from a hydraulic perspective, and it may be necessary for other reasons.

$$H_w/D = c\{Q/AD^{0.5}\}^2 + Y$$
$$\{Q/AD^{0.5}\}^2 = \{66/(7.07 \times 3^{.5})\}^2 = 29.05$$
$$H_w/D = 0.055(29.05) + 0.54 = 2.14 > 2, \text{ unacceptable}$$

Since $H_w/D > 2$, a 36 in pipe with simple projecting inlet should not be used. If the smaller size is still needed, alternative inlet configurations could be investigated.

Headwall: $H_w/D = 0.038(29.05) + 0.69 = 1.79 < 2$, marginally acceptable
Mitred: $H_w/D = 0.046(29.05) + 0.75 = 2.09 > 2$, marginally unacceptable

Thus, depending on base and subbase elevations, headwall and mitred inlets may permit use of a 36 in pipe. Other sophisticated inlet treatments can also be used to improve inlet efficiency. Their evaluation should be referred to an experienced hydraulic engineer.

This same problem can be evaluated by chart lookup. In Figure 12-4.1 (for simple projecting CMP culverts), locate Q = 66 ft^3/s on the horizontal axis and then draw a vertical line to the curve for $H_w/D = 1.5$. The required diameter is read from the vertical axis as approximately 1000 mm. The next size that keeps $H_w/D < 1.5$ is 1050 mm. Note that the curve for $H_w/D = 2$ is also above the 900 mm grid line at Q = 66, indicating that a 900 mm is inadequate even at the higher depth ratio.

Alternatively, the traditional design nomograph in Figure 12-4.2 can be used. Draw a line connecting D = 900 mm and Q = 1.87 m^3/s to the first (headwall) H_w/D axis. Note that the scales for mitred and projecting inlets are projected to the headwall scale before reading. This gives ratio values of 1.8, 2.1, and 2.2 for headwall, mitred, and projecting inlets, respectively.

Using Figure 12-4.2, draw a line connecting $H_w/D = 1.5$ and $Q = 1.87\ m^3/s$ to the diameter axis, giving D = 1000 mm; the next largest stock sizes are 1050 and 1200 mm. The H_w/D ratios for the 900 mm pipe can be checked by drawing a line through D = 900 mm and $Q = 1.87\ m^3/s$. This gives ratios of 1.8 (headwall) and 2.2 (mitred and projecting). Note that the mitred and projecting values are projected onto the headwall axis for reading.

Figure 12-4.1
Design Chart for Sizing Simple CMP Culverts Under Inlet Control

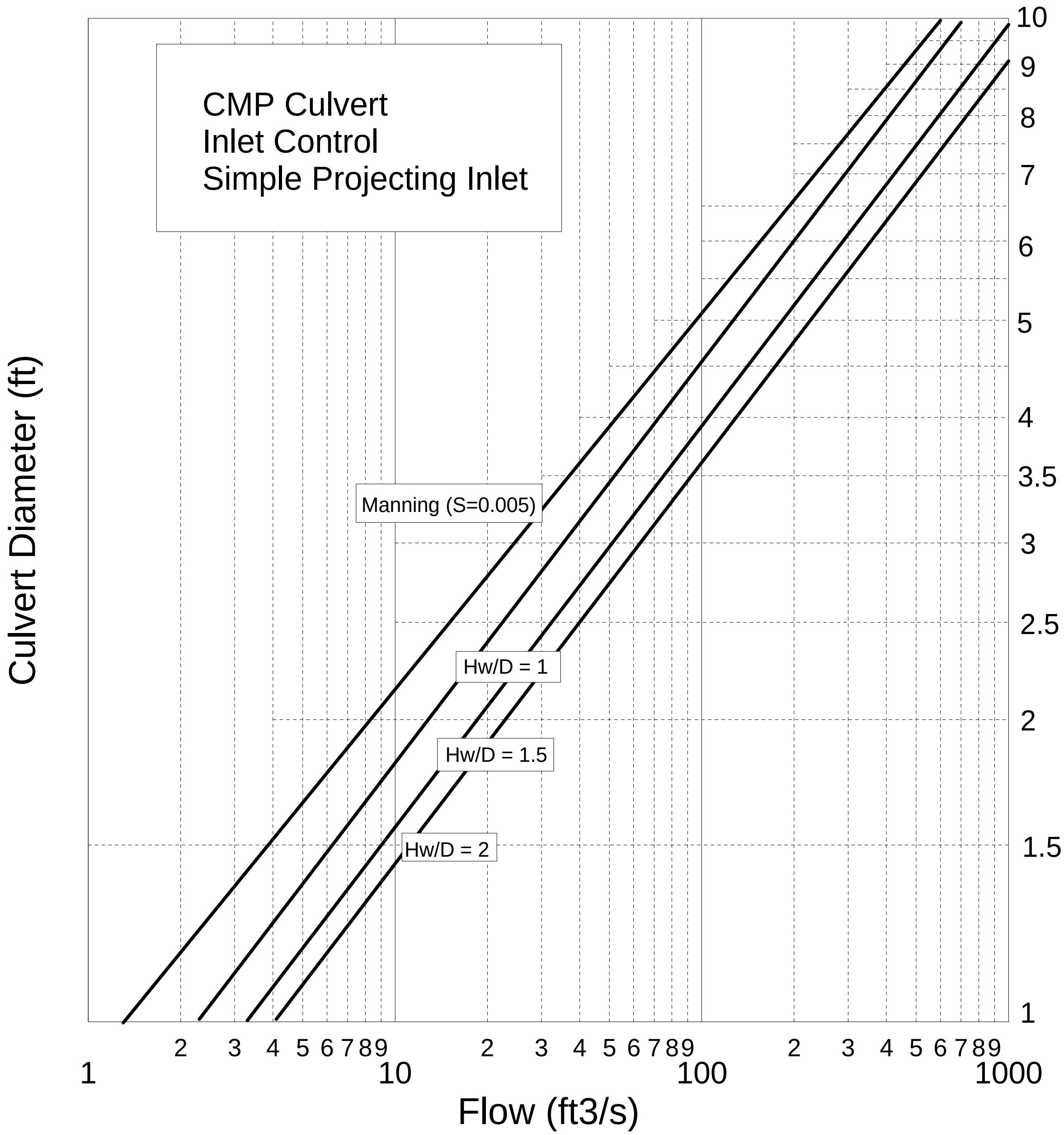
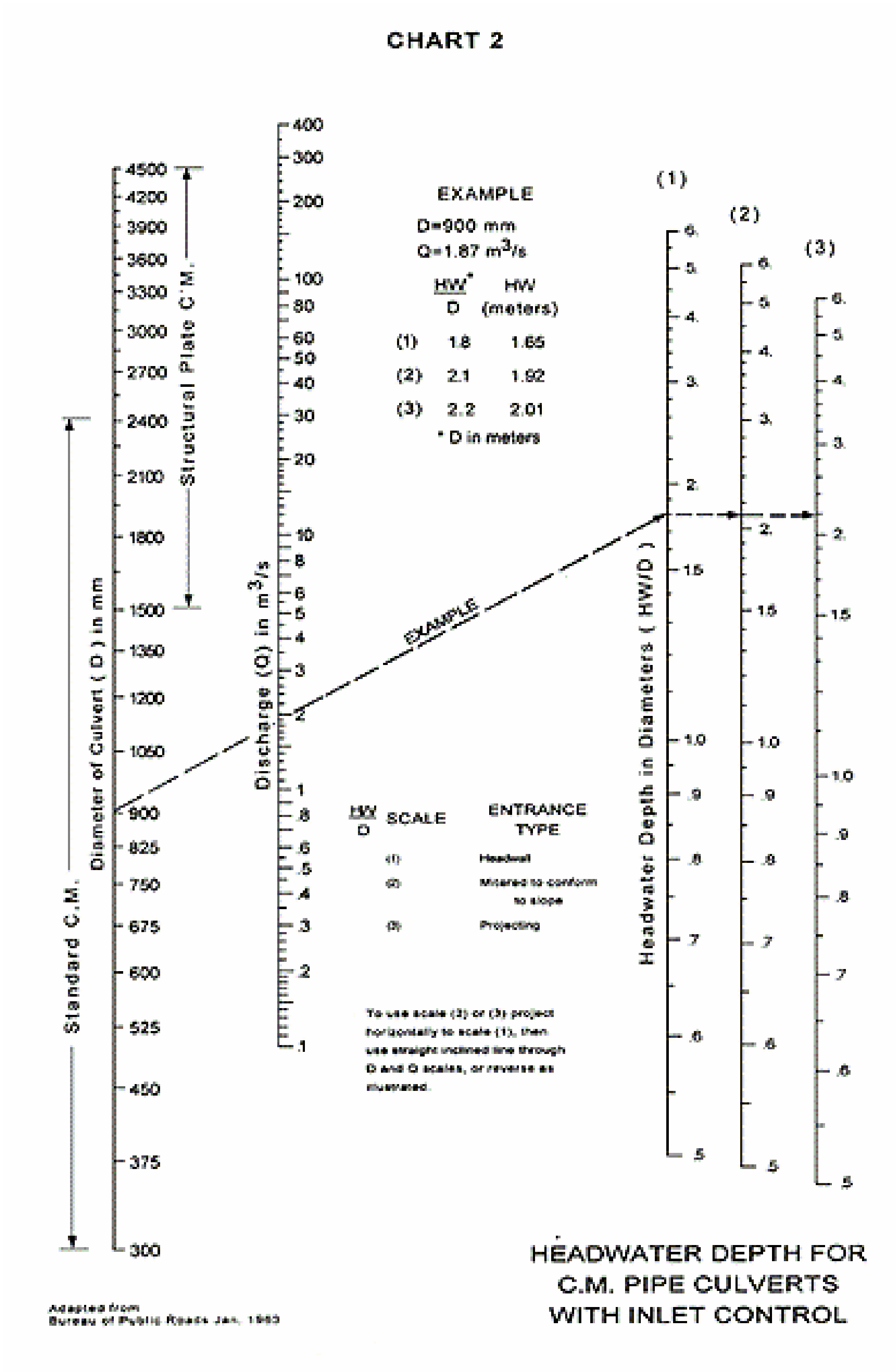


Figure 12-4.2
Design Nomograph for Sizing CMP Culverts Under Inlet Control



12-4.04 Tailwater

The simplified procedure recommended here is only suitable for cross-pipes that carry stormwater and not perennial streams. Hydraulic engineers in the Hydrology Section or Bridge Program should be consulted for perennial streams and situations where backwater may be expected.

12-4.05 Pipe Equivalences and End Areas

Culvert end-area information is summarized in Table 12-4.16 for both round and arch culverts. Table 12-4.17 gives multi-pipe equivalences as the number of smaller diameter pipes equal in hydraulic capacity to that of one larger size culvert. The table assumes that all other hydraulic factors are constant (e.g., material, slope, entrance type).

Table 12-4.16
CROSS-SECTIONAL END AREAS

Round Pipe			Pipe Arch	
Normal Diameter (in)	**End Area (ft^2)**	**Thickness (in)**	**End Area (ft^2)**	**Formed Diameter (in)**
12	0.790	0.060	0.72	14 x 10
15	1.227	0.060	1.1	17 x 13
18	1.767	0.060	1.5	21 x 15
21	2.400	0.060	2.2	24 x 18
24	3.142	0.075	2.8	28 x 20
30	4.909	0.075	4.4	35 x 24
36	7.068	0.105	6.4	42 x 29
42	9.621	0.105	8.7	49 x 33
48	12.566	0.105	11.4	57 x 38
54	16.000	0.105	14.3	64 x 43
60	19.635	0.135	17.6	71 x 47
66	23.758	0.135	21.4	77 x 52
72	28.274	0.164	25.5	83 x 57

Note: circular pipe $A = \pi D^2/4$ (D, A in consistent units)
pipe arch $A = 0.71(w \times h)^{1.023}$ (w & h in ft, A in ft^2)

It is almost always preferable to use a single culvert rather than multiple pipes with the same capacity. When a single circular pipe cannot be used (for example, due to headroom limitations) a low-profile alternative can often be substituted. However, there will always be the occasional circumstance where multiple pipes are the best choice. When choosing a number of identical smaller pipes with the capacity as a single larger pipe, there are two key mistakes to avoid:

- the number of pipes is *not* the ratio of larger diameter to smaller diameter, (D_L/D_S)
- the number of pipes is *not* the ratio of larger end area to smaller area, (A_L/A_S)

Rather, the number N of equivalent smaller pipes is given by the equation

$$N = (D_L/D_S)^{\beta}$$

where β is an exponent depending on the flow equation (Manning, $\beta = 8/3$; inlet control, $\beta = 5/2$)

Pipe equivalences by Manning's equation for fully flowing pipes are tabulated in Table 12-4.17. These give conservative results when applied to culverts under inlet control. Alternatively, the above equation can be used.

TABLE 12-4.17
MULTIPLE-PIPE EQUIVALENCES

Diameter of Larger Pipe (in)	Diameter of Smaller Pipe (in)									
	12	18	24	30	36	42	48	54	60	66
12	1									
18	3	1								
24	6	2	1							
30	12	4	2	1						
36		6	3	2	1					
42		10	4	2	2	1				
48			6	4	2	2	1			
54			9	5	3	2	2	1		
60			12	6	4	3	2	2	1	
66				8	5	3	2	2	2	1
72				10	6	4	3	2	2	2
78					8	5	4	3	2	2
84					10	6	4	3	3	2
90					12	8	5	4	3	2

Assumes fully flowing pipe by Manning's equation, $N = (D_L/D_S)^{8/3}$

<u>Example</u>: *How many 12 in culverts provide the same hydraulic capacity as one 24 in culvert?*

- *By look-up in Table 12-4.17, six (6) 12 in pipes are equivalent to one (1) 24 in pipe*
- *By calculation and assuming Manning's flow (same as Table 12-4.17)*
  $N = (24/12)^{8/3} = 6.35$
- *By calculation and assuming inlet control with $H_w/D = 1.5$*
  $N = (24/12)^{5/2} = 5.66$

12-4.06 Embedded Culverts and Design for Fish Passage Through Culverts

All new and replacement culverts on perennial streams should be designed so as to not present obvious obstacles to fish passage, even when the stream has not been identified as a specific fishery. Additional steps shall be taken when the culvert is in an identified fishery habitat. The document *Fish Passage Policy and Design Guide* (Maine DOT, 1/2005) presents policy and technical details. The Environmental Office should be consulted as to fish passage requirements for specific streams.

It is fairly common procedure to embed culverts in the natural stream substrate. Embedding a pipe reduces the available cross-section flow area as compared to the nominal end area. This area reduction must be accounted for in pipe sizing and may necessitate some degree of up-sizing. A simple correction can be applied by first sizing the pipe as if it were not embedded. Then choose an embedded pipe with the same open end area. Table 12-4.18 gives the equations for calculating open end areas of embedded circular pipes; Table 12-4.19 gives results for commonly used circular pipe sizes. Table 12-4.20 gives open areas for embedded elliptical pipe arches.

Table 12-4.18: Equations for Embedded Circular Pipe Geometry

Pipe Parameters	radius R, diam D, embed depth d_b
Embedded Area	$A_b = R^2\cos^{-1}[(R-d_b)/R] - (R-d_b)\{2Rd_b-d_b^2\}^{0.5}$
Open Area	$A_o = \pi R^2 - A_b$
Embedded Perimeter	$P_b = D\cos^{-1}[(R-d_b)/R]$
Open Perimeter	$P_o = \pi D - P_b$
Bottom Width	$w = \{4d_b(D - d_b)\}^{0.5}$
Distance from bottom to center	$d = R - d_b$

*Use consistent units

Table 12-4.19: Open End Areas (ft^2) for Embedded Circular Pipes

	Embedded Depth (in)					Embedded Depth (in)			
Dia (in)	3	6	9	12	Dia (in)	3	6	9	12
12	0.415	0.393	0.370	0.000	66	17.645	15.568	14.236	13.383
18	1.015	0.898	0.884	0.869	72	21.277	18.857	17.305	16.233
24	1.923	1.661	1.581	1.571	78	25.263	22.483	20.670	19.392
30	3.153	2.710	2.525	2.463	84	29.605	26.448	24.360	22.865
36	4.714	4.058	3.738	3.592	90	34.303	30.753	28.379	26.655
42	6.612	5.716	5.237	4.981	96	39.359	35.402	32.729	30.764
48	8.850	7.691	7.032	6.646	102	44.774	40.395	37.412	35.197
54	11.434	9.989	9.131	8.596	108	50.550	45.734	42.429	39.954
60	14.364	12.613	11.539	10.839	114	56.686	51.421	47.783	45.039
					120	63.185	57.457	53.475	50.452

(These equations and tables for embedded pipes can also be used to evaluate pipes flowing partially full. Then the depth of embedment is analogous to the depth of flow. This is discussed in further detail in Section 12-5.03.)

<u>Example</u>: *Hydrologic analysis indicates that a nominal 36 in pipe is needed to convey the 50-yr event. It is required that the pipe be embedded by 6 inches. What size pipe should be used?*

A 36 in pipe has an end area of $\pi(1.5\ ft)^2 = 7.07\ ft^2$. Use Table 12-4.19 under the column for 6 in embedding to find the size with open end area closest to $7.07\ ft^2$. The needed size is 48 in.

There are two situations where embedding is not generally recommended. In the case of an equalizer pipe where sluggish standing water is observed under low water conditions, the pipe need only be placed so that the invert is at the natural stream bottom elevation. In the case of steep streams, embedding may propagate a head upstream of the culvert. Therefore, simply matching the pipe invert to natural stream bottom is suggested. Staff with special expertise should be consulted in those instances where significant outlet drops have developed.

Table 12-4.20
OPEN AREA IN EMBEDDED ELLIPTICAL PIPE

	Span (ft)	Rise (ft)	Open Area (ft^2) Depth of Embedding (in) 0 in	6 in	9 in	12 in
Corner Radius = 18 in	6.08	4.58	22.03	19.95	18.64	17.24
	6.33	4.75	24.00	22.17	20.83	19.37
	6.75	4.92	26.17	24.47	23.06	21.54
	7.00	5.08	28.29	26.36	24.88	23.29
	7.25	5.25	30.53	28.38	26.82	25.15
	7.67	5.42	32.94	30.94	29.34	27.60
	7.92	5.58	35.23	33.01	31.32	29.51
	8.17	5.75	37.70	35.20	33.41	31.51
	8.58	5.92	40.27	38.01	36.27	34.27
	8.83	6.08	42.87	40.34	38.44	36.40
	9.33	6.25	45.78	43.48	41.59	39.50
	9.50	6.42	48.44	46.02	43.89	41.72
	9.75	6.58	51.29	48.42	46.29	44.02
	10.25	6.75	54.32	51.82	49.74	47.43
	10.67	6.92	57.48	55.11	52.96	51.00
	10.92	7.08	60.61	58.04	55.90	53.49
	11.42	7.25	64.01	61.61	59.61	57.25
	11.58	7.42	67.08	64.49	62.24	59.83
	11.83	7.58	70.40	67.59	65.24	62.61
	12.33	7.75	74.09	71.47	69.30	66.73
	12.50	7.92	77.40	74.58	72.15	69.51
	12.67	8.08	80.93	77.85	75.59	72.39
	12.83	8.33	85.48	82.07	79.33	76.38
	13.42	8.42	88.44	85.39	82.84	79.89
	13.92	8.58	92.52	89.67	87.30	84.50
	14.08	8.75	96.25	93.19	90.55	87.65
	14.25	8.92	100.07	96.76	84.16	90.84
	14.83	9.08	104.57	101.50	98.95	96.21
	15.33	9.25	108.90	106.02	103.61	100.77

	Span (ft)	Rise (ft)	Open Area (ft^2) Depth of Embedding (in) 0 in	6 in	9 in	12 in
	15.50	9.42	112.93	109.86	107.30	104.28
	15.67	9.58	117.09	113.81	111.08	105.54
	15.83	9.83	122.64	119.11	116.17	112.73
	16.42	9.92	126.19	122.91	120.18	116.96
	16.58	10.08	130.55	127.05	124.13	120.68
Corner Radius = 31 in	13.25	9.33	97.69	95.03	92.68	90.27
	13.50	9.50	101.79	98.94	96.58	93.90
	14.00	9.67	106.29	103.59	101.34	98.70
	14.17	9.83	110.24	107.38	104.96	102.24
	14.42	10.00	114.53	111.46	108.91	106.01
	14.92	10.17	119.28	116.39	113.98	111.14
	15.33	10.33	123.84	121.07	118.76	116.05
	15.58	10.50	128.39	125.47	123.03	120.17
	15.83	10.67	133.08	129.89	127.23	124.10
	16.25	10.83	137.80	134.85	132.39	129.51
	16.50	11.00	142.60	139.49	136.89	133.86
	17.00	11.17	147.81	144.67	142.06	138.99
	17.17	11.33	150.80	147.65	145.03	141.94
	17.42	11.50	157.56	154.24	151.47	148.22
	17.92	11.67	163.02	159.86	157.23	154.12
	18.08	11.83	167.92	164.60	161.83	158.56
	18.58	12.00	173.54	170.36	167.71	164.58
	18.75	12.17	178.64	175.30	172.52	169.23
	19.25	12.33	184.47	181.25	178.57	175.42
	19.50	12.50	190.01	186.63	183.83	180.52
	19.67	12.67	195.37	191.82	188.91	185.44
	19.92	12.83	201.11	197.39	194.29	190.63
	20.42	13.00	207.17	203.64	200.69	197.21
	20.58	13.17	212.72	209.00	205.91	202.25

12-5 PAVEMENT DRAINAGE

12-5.01 Drainage Appurtenances

The purpose of pavement drainage is to remove the storm water from the pavement through a combination of drainage features and then discharge it into a receiving watercourse, reservoir, or conduit system. The pavement drainage system includes curb and gutter, grate inlets, catch basins, manholes, and the underground pipe conduit system ("closed system"). The Department's Standard Detail Sheets provide the geometry and structural details for those drainage appurtenances approved for use by the Department.

By their nature, closed systems have limited capacity and therefore are designed for just the 10-year event instead of the much larger 50-year event. Standard gutters and inlets can only accommodate relatively small flows; pipe capacity may be limited by physical constraints. Every effort should be made to limit the introduction of off-pavement runoff into the closed system and to divert that runoff into alternative drainage paths.

Catch Basins and Manholes

A catch basin conveys stormwater into the subsurface storm drain system. It typically includes a grate or curb inlet at ground surface where stormwater enters the catch basin and a cylindrical subsurface structure that provides connections to the underground drain system. This structure is often called the "catch basin", separate from the surface inlet. The lower volume of the catch basin may be below the outlet pipe invert, in which case that volume acts as a sump to capture sediment, debris and associated pollutants. Catch basins act as pretreatment for other treatment practices by capturing large sediments. The performance of catch basins at removing sediment and other pollutants depends on the design of the catch basin (e.g., the size of the sump), and routine maintenance to retain the storage available in the sump to capture sediment.

A manhole provides access to the underground pipe system for inspection and cleaning. They are located where system parameters change, including direction, pipe size, grade, and at pipe junctions. Manholes are also placed at regular intervals (300 ft – 500 ft; 90 – 150 m) on long uniform straight segments in order to provide general access.

The following provides selection criteria for the types of catch basins presented in the Standard Details:

1) Type 1 and Type 2: use along roadside curbs, median curbs, and in parking lots.
2) Type 5: use to avoid a utility.
3) Type E: use off the highway (e.g., lawns)
4) Type F: use on lawns and for shallow highway drainage systems

The following provides selection criteria for catch basin tops:

1) Type A: use with granite curb.
2) Type B: use with granite edging and bituminous curbs.
3) Type C: use in areas protected from vehicular travel.
4) Type D: use at manholes.
5) Cascade Type: use in urban areas.

Manholes are required where there is

1) a change in direction;
2) a change in pipe size; or
3) a junction of two or more lines.

Catch Basins and Inlets

The following guidance applies to the location of catch basins:

1) Regardless of the results of the pavement drainage analysis, catch basins and inlets should be spaced no more than 300 ft (90 m) apart.
2) Catch basins should be placed on the high side of bridge approaches.
3) If the location, according to the hydraulic analysis, falls within an intersection, driveway entrance area, curb-cut ramp, or pedestrian crosswalk, the catch basin should be placed on the high side of the feature.
4) Catch basins should be placed to capture the side street flow before it reaches the major highway.
5) On superelevated curves, catch basins should be placed to prevent water from sheeting across the highway.
6) In sag locations where the catch basins will be the only outlet for stormwater (i.e., no overflow path is available), additional catch basins should be installed flanking the low point. Flank locations should be determined using methods in this manual, with the flanking inlets a minimum of 4 in (100 mm) above the elevation of the sag inlet.
7) In sag locations on freeways, four catch basins (two on each side of the roadway) are typical – one on each side of the roadway usually on the flatter of the two longitudinal upgrades.
8) Where granite curb is proposed, the catch basin must be located in a full-height curb section and not within a terminal curb section.

Closed Systems

1) Do not use pipe sizes less than 12 in (300 mm) (although 6 in underdrain is acceptable as the first section of pipe upgradient of the first inlet)

2) It is desirable to have a 3 in (75 mm) difference in elevation between the inlet pipe and the outlet pipe in a catch basin
3) Desirably, the pipe will have a cover of at least 2 ft (0.6 m) below the subgrade. The minimum cover for any pipe is 1 ft (0.3 m) below subgrade.
4) Pipes that run transversely from catch basin to catch basin will be non-perforated.
5) Pipes that run longitudinally from catch basin to catch basin may be perforated, with perforations up.
6) Wherever possible, system pipes that cross under a road shall have a minimum size of 18 in (450 mm) in order to facilitate regular maintenance and anticipate future drainage growth.
7) Closed system pipes that abut an upgradient combined (sanitary and storm) system shall be sized to accept the existing and projected storm flow components of the combined system for the eventuality of future separation of the combined system.
8) Catch basins should have a sump of at least 2 ft (0.6 m) beneath the lowest pipe invert.
9) Catch basin and manhole outlet pipes should be at least as large as the largest inlet pipe.

12-5.02 Hydraulic Analysis of Gutters and Inlets

This section gives design calculation procedures for the most commonly encountered gutter and inlet configurations. A complete development of gutter flow equations is given in the appendix. Designers should refer to the FHWA documents HEC #12 and HEC #22 for general background and techniques for additional configurations. It is recommended that MDOT staff use spreadsheets prepared by the Hydrology Section for routine gutter and inlet design.

Basic Design Controls

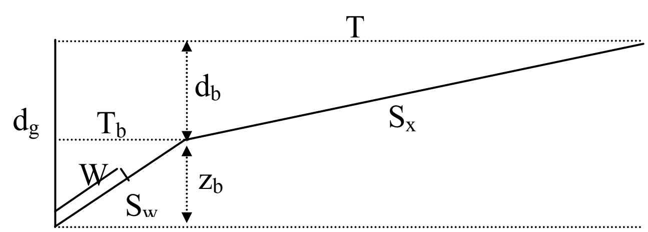
1) Frequency: the design frequency recommended for closed systems is a 10-year return period with storm duration no less than 5 minutes.
2) Hydrologic Method: the Rational Method will typically be used for pavement drainage; other methods may be used in consultation with MDOT Hydrology Unit.
3) Allowable Water Spread "T": Table 12-5.1 presents the maximum allowable water spread width "T" on the highway pavement during the design flood frequency.
4) Minimum Grade: the centerline profile on highways and streets with curb should have a minimum gradient of 0.25% (0.0025 m/m). Desirably, the minimum grade will be 0.5% (0.005 ft/ft).
5) Cross-section Slope: slope from centerline to curb shall be at least 2% (0.02 ft/ft)
6) Inlet Spacing: inlets should be spaced no more than 300 ft (90 m) apart

Table 12-5.1
ALLOWABLE WATER SPREAD "T"

Type of Facility	Allowable Water Spread T
Freeways & Other Multilane Highways	Shoulder width or curb offset
Two-lane arterials	Shoulder width or curb offset plus 2 ft (0.6 m) of travelway (typical T = 10 ft = 3 m)
Two-lane Collectors & Locals	Shoulder width or curb offset plus ½ of travelway
Ramps	Shoulder width or curb offset

<u>Gutter Hydraulics</u>
A composite triangular gutter typically terminates at a vertically-walled curb. Flow is controlled by surface roughness n, slopes S_x and S_w in cross-section, longitudinal slope S along the curb length, allowable water spread width T, and distance T_b from curb to break in cross-slope. At locations to be determined, inlets of width W intercept and convey flow to the subsurface closed drainage system. A schematic of gutter flow geometry is shown in Figure 12-5.1.

Figure 12-5.1: General Triangular Gutter Geometry Schematic



The depressed section in a composite shape ($S_w > S_x$) creates additional gutter flow capacity and thereby provides several advantages, including increased catch basin spacing (and fewer catch basins) for a given flow. Alternatively, a composite section can be employed to reduce spread onto the road. The standard MDOT design cross-section utilizes $S_x = 0.02$ (2%).

A simple uniform right-triangular section is obtained by setting $S_w = S_x$. Basic geometry and Manning's hydraulics of a right-triangle gutter channel (uniform S_x) are summarized in Table 12-5.2.

The equations for a composite section are more complicated, but with the ready availability of dedicated computer spreadsheets and programs, design of composite sections is straightforward. The equations are summarized in Table 15-5.3 below. These equations are amenable to manual calculation in a paper-and-pencil worksheet in the order shown, composite sections are best analyzed by computer.

Table 12-5.2: Simple Right-Triangle Channel Geometry and Hydraulics

T, S_x, W		Specified design parameters
Flow depth at curb	d_g	S_xT
Flow depth at inlet edge	d_w	$S_x\{W/(1+S_x^2)^{1/2}\}$
Gutter capacity	Q_g	$(3/8)(\lambda S^{1/2}/n)S_x^{5/3}T^{8/3} = (3/8)(\lambda S^{1/2}/n)d_g^{8/3}/S_x$
Intercepted flow	Q_w	$(3/8)(\lambda S^{1/2}/n)S_x^{5/3}\{T^{8/3}-(T-W)^{8/3}\}=(3/8)(\lambda S^{1/2}/n)\{d_g^{8/3}-d_w^{8/3}\}/S_x$
Interception efficiency	E_o	$Q_w/Q_g = 1 - \{1-W/T\}^{8/3}$
Manning's unit conversion	λ	1.486, U.S. Customary; 1, metric
Manning's roughness	n	asphalt, 0.013; concrete, 0.016

Table 12-5.3: Composite Triangle Channel Geometry and Hydraulics

T, T_b, S_x, S_w, W		Specified design parameters
Projected inlet width	W_x	$W/(1+S_w^2)^{1/2}$
Flow depth at curb	d_g	$S_x(T-T_b)+S_wT_b$
Flow depth at slope break	d_b	S_wT_b
Flow depth at inlet edge	d_w	$S_x(T-T_b)+S_w(T_b-W_x)$
Gutter capacity	Q_g	$(3/8)(\lambda S^{1/2}/n)\{(d_g^{8/3} - d_b^{8/3})/S_w + d_b^{8/3}/S_x\}$
Intercepted flow	Q_w	$(3/8)(\lambda S^{1/2}/n)\{d_g^{8/3} - d_w^{8/3}\}/S_w$
Interception efficiency	E_o	Q_w/Q_g
Manning's unit conversion	λ	1.486, U.S. Customary; 1, metric
Manning's roughness	N	asphalt, 0.013; concrete, 0.016

Inlets

Inlets are structures placed in the gutter in order to convey water via a catch basin into the closed drainage system buried in the ground. Standard inlets are 2 ft x 2 ft (0.6 m x 0.6 m) square. Two types are commonly used, parallel bar and cascade. Cascade inlets are preferred in urban areas, since they are safe for bicycle traffic. Cascade inlets may have slightly smaller hydraulic capacity.

The problem in gutter and inlet design is to space the inlets so that gutter runoff does not extend beyond the design spread T value. Mathematically, inlets are spaced so that design runoff spread exactly equals the specified design T value at each inlet.

It is inefficient to space inlets so that the entire gutter flow is captured. Instead, a certain amount of flow is intentionally allowed to bypass an inlet and flow to the next inlet. Based just on simple geometry, the "frontal flow" ratio of captured flow Q_w to total gutter flow Q_g is

$$E_o = Q_w/Q_g$$

Efficiency equations for uniform and composite sections are in the tables above.
For example, an inlet that is just 20% of the spread T captures 45% of the frontal flow in a uniform section.

Some the approaching flow within the capture width W may bypass the inlet by "splash over" when velocities are excessive. A conservative assumption that no more than 5% (equivalently, interception efficiency R_f = 95%) splashes over simplifies the analysis; this can be addressed in more detail if necessary. Then the overall capture efficiency E is

$$E = R_f E_o = 0.95E_o$$

It follows that the inlet and bypass flows, Q_i and Q_b, are given by

$$Q_g = Q_i + Q_b \quad = EQ_g + Q_b$$
$$Q_b = (1\text{-}E)Q_g \quad \text{and} \quad Q_i = EQ_g$$

These equations pertain to the hydraulic capacities of gutter and inlet; they do not refer to the actual amount of runoff (the hydrology) in the system.

Gutter Hydrology

Ideally, the only runoff entering a closed system originates on the paved surface. Runoff Q_p generated on the pavement is calculated by the Rational Method, modified for dimension units (ft or m) convenient to pavement sections:

$$Q_p = \mu^* C i w_R L_b$$

Where Q_p = pavement runoff (ft^3/s or m^3/s)
μ^* = unit conversion coefficient (1/43560 for U.S. Customary; 0.28×10^{-6} for metric)
C = runoff coefficient (1 for pavement)
i = 10-year, 5-minute rainfall intensity
(5.55 in/hr = 141 mm/hr for suitable for most locations inMaine)
w_R = roadway runoff-generating width (ft or m)
L_b = distance between inlets (ft or m)

Note that Rational Equation has been rewritten in units (ft and ft^2 instead of ac) more appropriate to the relatively small runoff-generating pavement segments. All terms on the righthand side except L_b are known. When additional off-project runoff Q_o must be accounted for, total runoff Q_r in the gutter is given as

$$Q_r = Q_p + Q_o$$

where Q_o is assumed to known or estimated.

Determination of Inlet Spacing

Inlet spacing is determined by combining the hydraulics and hydrology of the system. Configurations of arbitrary complexity can be accommodated, though most projects will be straight-forward. Systems subject to significant offsite runoff should be referred to hydraulic engineering staff or the Hydrology Section. The remainder of this section is limited to runoff generated on simple rectangular pavement areas, suitable for Rational Method analysis.

In all cases, inlets are located so that spread at an inlet just equals the maximum allowable design value T. Between inlets, the actual spread increases to the design limit as the gutter captures an increasing area of runoff-generating pavement. By setting the gutter flow capacity Q_g (from hydraulics) equal to total predicted gutter flow (from hydrology), the distance between inlets can be calculated. The predicted gutter flow consists of two components, bypass Q_b from the previous inlet and pavement runoff Q_p generated since the previous inlet. Since spread at an inlet is set equal to the specified T, the generated pavement runoff Q_p must equal the flow Q_i entering the inlet. Equating gutter capacity (hydraulics) to gutter flow (hydrology) at an inlet gives

$$\begin{aligned} Q_g &= Q_b + Q_i \\ &= (1\text{-}E)Q_g + Q_p \\ Q_p &= EQ_g = Q_i \qquad \text{(flow into the inlet)} \end{aligned}$$

The runoff quantity Q_p is determined by hydrologic calculation, e.g. Rational Method. Substituting for Q_p with the Rational Formula and solving for inlet spacing L_b gives

$$L_b = \{1/\mu^{*}Ciw_R\}Q_i = 7850Q_i/w_R \text{ (U.S. Customary)}$$

Inlet spacing on roads of uniform grade and no offsite runoff can be read from Figures 12-5.2 that follow, provided the road satisfies the default conditions in Table 12-5.3. These figures allow determination of inlet spacing for various combinations of profile slope S and cross-section slope S_x, subject to the assumed parameter values appropriate for arterial roads in Table 12-5.3. These figures have a maximum vertical scale of 400 ft (125 m); maximum allowable spacing between inlets is 300 ft (90 m).

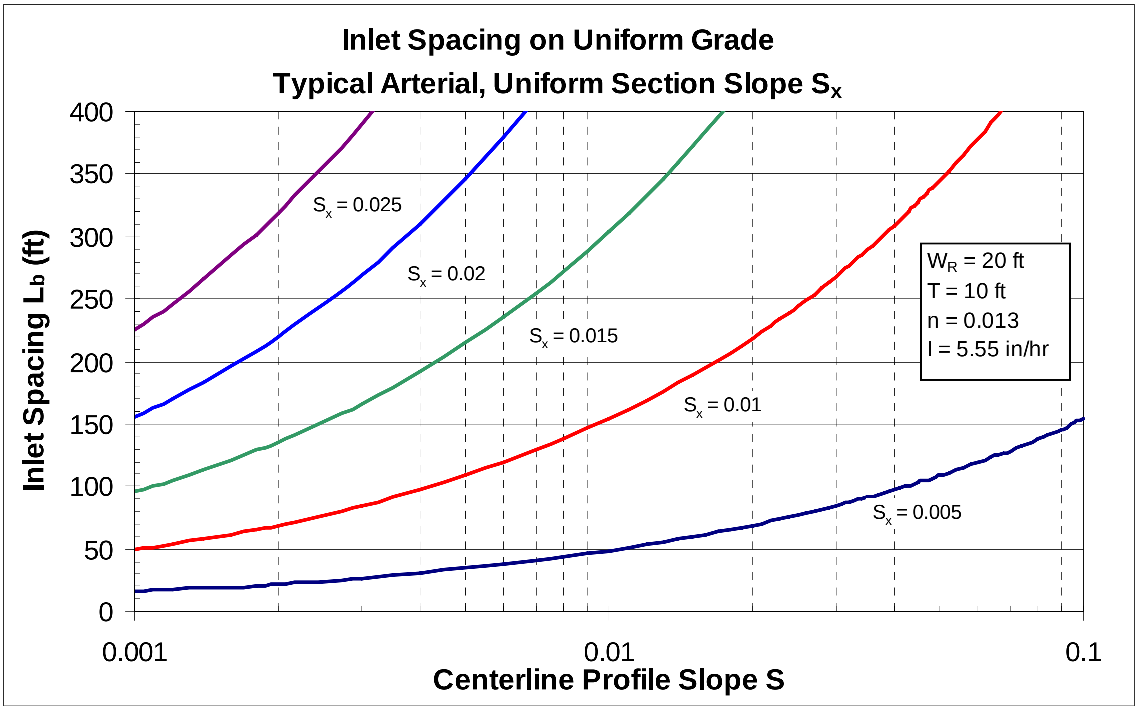
Note that, in Figures 12-5.3, for the standard design value $S_x = 0.02$ the maximum spacing of 300 ft (90 m) is acceptable over most of the range of centerline profiles. In such cases, other design considerations (e.g., intersections, side streets) may require spacing less than this maximum. In marginal situations, additional gutter capacity, reduced spread, and increased spacing can be achieved by using a composite gutter cross-section.

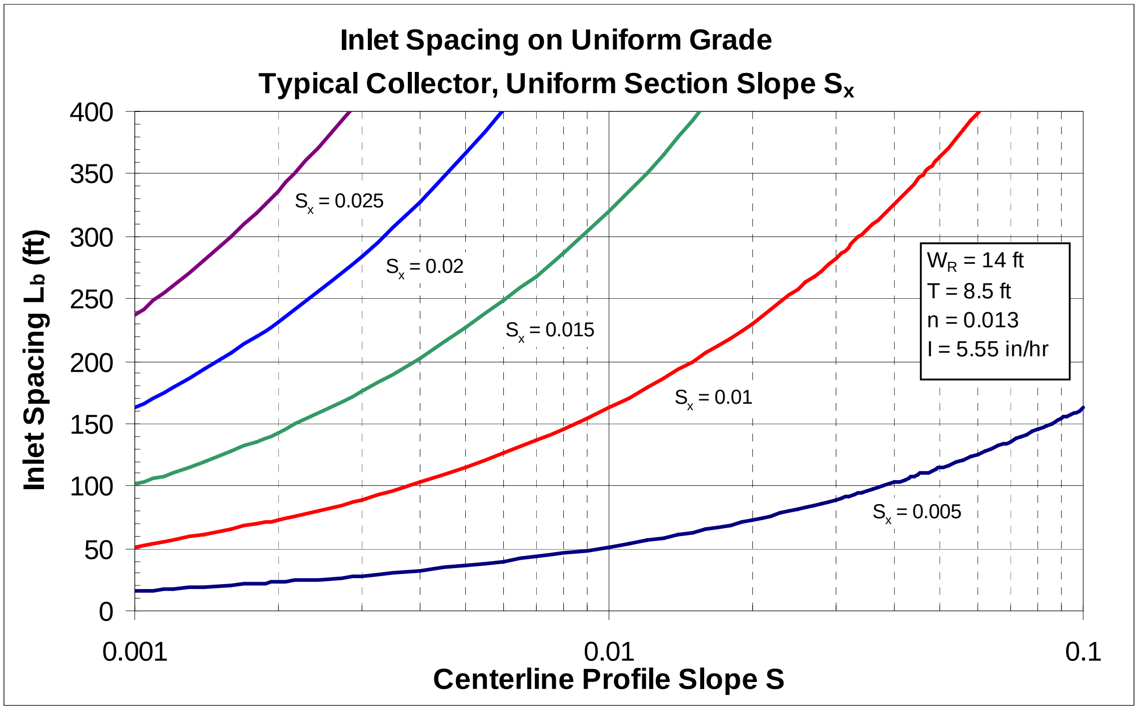
Table 12-5.4: Parameters for Simplified Inlet Spacing Analysis on Arterial Roads

Parameter	Symbol	Value
Road half-width	w_R	20 ft (6 m)
Allowable water spread on road	T	10 ft (3 m)
Time of concentration	t_c	5 min
Return Period	T	10 yr
Design Rainfall Intensity	i_{10}	5.5 in/hr (140 mm/hr)
Runoff Coefficient	C	1
Off-pavement runoff	Q_o	0 ft^3/s

Significant departures from the assumptions in Table 12-5.3 warrant a careful engineering analysis. In particular, inlet systems are easily overwhelmed by the introduction of off-pavement runoff. At the very least, it is desirable to introduce concentrated off-pavement runoff into the closed system via stub connections into manholes or catch basins, rather accept the runoff into the gutter and inlet system. In the event that off-pavement contributions cannot be re-directed, it is imperative that a complete analysis be performed.

Figure 12-5.2: Inlet Spacing for Simplified Design Scenarios





Example: Inlet Spacing

What is the maximum spacing between inlets on an asphalt arterial with centerline slope S = 0.008? Site constraints limit the cross-sectional slope to $S_x = 0.01$. There is no off-pavement runoff. Assume a simple uniform section and standard inlet W = 2 ft.

By Chart Look-up: Since "arterial" is specified, the assumptions of half-width = 20 ft and spread T = 10 ft are acceptable. The standard design storm for closed systems is the 10-year storm. Thus, the conditions in Table 12-5.2 are satisfied and it is appropriate to use Figures 12-5.2 to estimate inlet spacing.

Use the figure for asphalt paving (n = 0.013). Locate S = 0.008 on the horizontal axis. Draw a vertical line from the horizontal axis to intercept the curve for $S_x = 0.01$. Draw a horizontal line from this intersection point to the vertical axis. This is the required inlet spacing: 140 ft.

By calculation:
Gutter Capacity $Q_g = \lambda(0.375/n)S_x^{1.67}S^{0.5}T^{2.67} = (0.376/0.013)0.01^{1.67}0.008^{0.5}10^{2.67} = 0.822\ ft^3/s$
Frontal Flow Capture Ratio $E_o = Q_w/Q_g = 1 - (1\text{-}W/T)^{2.67} = 1 - (1 - 2/10)^{2.67} = 0.45$
Overall Capture Efficiency $E = R_fE_o = (0.95)(0.45) = 0.43$
Inlet Flow $Q_i = EQ_g = (0.43)(0.822) = 0.353\ ft^3/s$
Bypass Flow $Q_b = Q_g - Q_i = 0.469\ ft^3/s$
Inlet spacing: $L_b = 7850Q_i/w_R = 7850(0.353)/20 = 139$ ft

Example: Inlet Spacing

What is the maximum spacing between inlets on an asphalt road with centerline slope S = 0.01? The road is through a residential area; half-width is 13 ft with a 3.3 ft shoulder; allowable spread T has been set at 6.6 ft. Site constraints limit the cross-sectional slope to $S_x = 0.01$. The road is a critical route to the local hospital for which no detour is available. Homeowners have traditionally discharged their stormwater and cellar drains to the roadway.

The assumptions in Table 12-5.2 are violated are numerous counts:

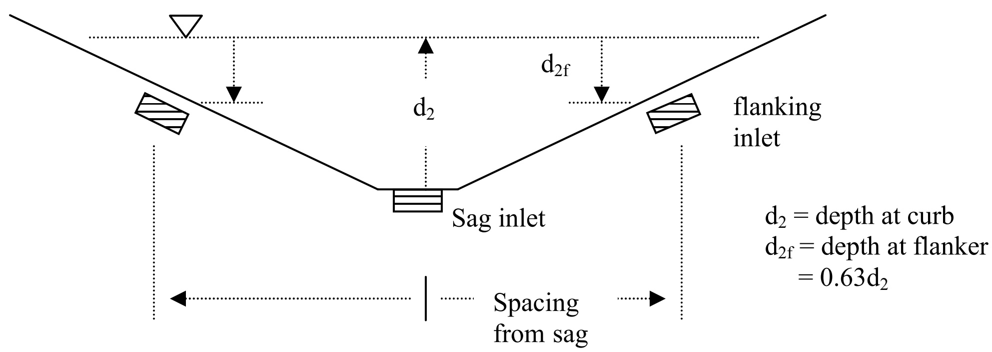
- the road is significantly narrower than an arterial
- allowable spread T is smaller
- critical route suggests that higher return period be considered
- there may be significant off-pavement runoff entering system

This problem is beyond the simplified methodology using the design charts in Figure 12-5.2. The designer should consult with staff hydraulic engineers or the Hydrology Section to be sure that the critical hydraulic and hydrologic issues are addressed in the design.

Grate Inlet Capacity – Inlet at Sag Low Point

Runoff is often conveyed in closed systems to the low (sag) point between two grades. From there the runoff is routed into a natural or constructed drainage feature and ultimately to a natural discharge. Inlets must be placed in the sag to prevent the accumulation of standing water on the road. Unlike inlets on a grade, sag inlets receive water from both directions and there is no bypass flow. The sag inlet must accept the entire design flow while not exceeding the acceptable design spread T. Figure 12-5.3 shows a curb line profile schematic of a sag inlet with adjacent flanking inlets.

Figure 12-5.3: Schematic Profile for Design of Sag and Flanking Inlets



As with inlets on a continuous grade, the design objective for sag inlets is to prevent gutter flow spread from exceeding the maximum allowable T. Analysis is somewhat more complicated, since flow into the inlet can take one of two forms, weir or orifice. In either case, flow is driven by average depth d of water over the grate. This in turn is a function of the design spread T and cross-section slope S_x. Grates are generally sized to operate as weirs, as this is a conservative design and assures additional capacity under orifice conditions at higher flows. In cases of both weir and orifice flow, the flow rate is determined by the average depth of water at the inlet.

Simplified Procedure for Sizing Sag Inlets and Calculating Inlet Capacity

The following procedure can be used to calculate the size of sag inlets. This procedure is straightforward and can be executed manually. However, specially prepared computer spreadsheets are recommended. This procedure should only be used in simple situations where off-pavement runoff is excluded from the road and the gutter section is simple triangular. Hydraulic engineering staff or the Hydrology Section should be consulted in cases where excessive inlet capacity is indicated, as subtle differences in weir and orifice flow are not included in this method.

1) Estimate design flow: the design flow at the sag consists of 4 components

   a. Bypass from upgradient right inlet

b. Bypass from other upgradient left inlet

Quantities for (a) and (b) should be available from the calculations for the last grade inlets immediately upgradient of the sag using methods of the previous section.

c. Pavement runoff between sag and right upgradient inlet
d. Pavement runoff between sag and left upgradient inlet

Quantities (c) and (d) are calculated using the Rational Method. For i_{10} = 5.55 in/hr and road half-width w_R = 20 ft, the Rational formula is

$$Q = CiA(ft^2)/43560 = 2.30x10^{-5}L\ ft^3/s$$

where L = distance (in ft) from sag to nearest upgradient inlet (calculate for right and left sides of sag).

These four components are summed to get the total design flow Q_i at the sag inlet.

2) Calculate average water depth d_{av} over the sag inlet

For a simple triangular gutter,

Depth at curb: $d_2 = S_xT$
Average depth over inlet: $d_{av} = S_xT - \{0.5S_x/(1+S_x^2)^{0.5}\}W$

3) Specify an inlet width W (usually 2 ft (0.6 m))

4) Calculate inlet length L_i assuming weir flow into inlet

Weir flow equation: $Q_i = C_wPd_{av}^{1.5}$
where C_w = weir coefficient = $(8g/27)^{1/2}$
= 3.0 $ft^{1/2}$/s U.S. Customary; 1.66 $m^{1/2}$/s metric
P = flow perimeter ($2L_iW$, free-standing; $2W+L_i$, against curb)

$L_i = Q_i/(C_wd_{av}^{1.5}) - 2W$ (inlet against curb)
$L_i = Q_i/(C_wd_{av}^{1.5}) - W$ (free-standing inlet)

Ordinarily, sag inlets are sized to function as weirs as this produces conservative results. If the resulting size is too big, proceed with step 5; otherwise, skip to step 6.

5) If L_i is unacceptably large, calculate L_i assuming orifice flow into inlet

Orifice flow equation: $Q_i = 0.67A_g(2gd_{av})^{0.5}$

$$L_i = Q_i/\{0.67(2gd_{av})^{0.5}a_gW\}$$

Where g = acceleration due to gravity = 32.2 ft/s^2 (9.81 m/s^2)

a_g = grate relative open area as a decimal fraction (0.35, cascade; 0.6, parallel bar)

A_g = inlet clear area = a_gL_iW

If L_i by orifice flow is still unacceptably large, then additional upgradient inlets should be inserted between the sag and the inlets immediately upgradient. This approach can also be combined with using a larger, non-standard inlet width W. Repeat the process until an acceptable sag inlet length is achieved.

6) Locate upgradient flanking inlets:

Flanking inlets are intended to relieve ponding of water on grade if the sag inlet becomes clogged. A design procedure for locating flanking inlets is given in the next section.

This procedure can be modified to calculate the capacity of a specified inlet size. Then the hydrologic calculations are omitted and the hydraulic capacity ("Q") equations are used. Two capacities are calculated, for weir and orifice conditions. The lesser of the two results is used to give a conservative estimate of inlet capacity.

Example: sag inlet capacity

Problem: Determine the capacity of a 2 ft x 2 ft against-curb parallel bar grate in a sag

Given: $S_x = 0.042$, $T = 8$ ft, curbed roadway, parallel bar grate ($a_g = 0.6$)

Preliminary calculations:

$d_{av} = S_xT - \{0.5S_x/(1+S_x^2)^{0.5}\}W = (0.042)(2.44) - \{0.5 \text{ x } 0.042/(1 + 0.042^2)^{0.5}\}(2)$
$= 0.29$ ft (average depth over inlet)
$P = 2W + L$ (curbed) $= 2(2) + 2 = 6$ ft
$A_g = a_gA = 0.6(LW) = 0.6(2 \text{ x } 2) = 2.4$ ft^2 (grate clear area)

Calculate capacity for weir and orifice flows:

$$Q_{weir} = C_wPd^{1.5} = 3.0(6)(0.29^{1.5}) = 2.8 \text{ ft}^3/\text{s}$$

$$Q_{or} = 0.67(2gd_{av})^{0.5}A_g = 0.67(2 \text{ x } 32.2 \text{ x } 0.29)^{0.5}(2.4) = 7.0 \text{ ft}^3/\text{s}$$

The conservative estimate of inlet capacity is the smaller of the two results, 2.8 ft^3/s.

Example: sag inlet sizing

Problem: Determine the parallel bar inlet size and curb water depth for an against-curb sag inlet. Standard inlet width is W = 2 ft.

Given: $Q_i = 6.7\ ft^3/s$; $S_x = 0.05$ m/m; n = 0.016; T = 10 ft; W = 2 ft; $a_g = 0.6$

Calculations:

Curb water depth: $d_2 = S_xT = (0.05)(10) = 0.5$ ft

Average depth over grate: $d = S_xT - \{0.5S_x/(1+S_x^2)^{0.5}\}W$
$= (0.05)(10) - \{0.5x0.05/(1 + 0.05^2)^{0.5}\}(2) = 0.45$ ft

Design for weir flow: $L = Q_i/(3.0d^{1.5}) - 2W = (6.7)/(3.0 \text{ x } 0.45^{1.5}) - 2(2)$
$= 3.4$ ft (P = L+2W = 7.4 ft)

Design for orifice flow: $L = Q_i/\{0.67(2gd_{av})^{0.5}a_gw_i\} = (6.7)/\{0.67(2x32.2x0.45)^{0.5}(0.6x2)$
$= 1.55$ ft

Final design: use weir flow results as they give larger inlet, hence more conservative combination of standard inlets that give P ≥ 7.4 ft
use a 2 ft x 4 ft inlet or two 2 ft x 2 ft inlets (perimeter P = 8 ft)

Example: sag inlet sizing with blockage

Problem: Re-size the inlet in the previous example, assuming 50% of open area blocked.

Design Objective: In weir flow, the objective in allowing for blockage is to preserve the same effective perimeter that accepts the design flow.

Assumptions: design for blockage requires the designer to make assumptions about the nature of the blockage. For example, 50% blockage along the width w_i, 50% blockage along the length L, and 30% blockage along L and w_i all produce the same 50% reduction in area. Assume 50% reduction in w_i.

Preliminary calculations:

Perimeter adjustment for blockage:

from previous example, effective perimeter P = 8 ft is required to accept Q_i
$P_{eff} = (0.5)2W + L = 8$ ft (0.5 factor is for assumed model of inlet width blockage)
$L = 8 - W$

Try reasonable L and W combinations to preserve $P_{eff} \geq 8$ ft:

W = 2 ft: $L \geq 6$ ft
W = 3 ft: $L \geq 5$ ft

The key parameter for maintaining capacity is the effective perimeter. The following configurations all preserve $P_{eff} = 8$ ft:

- two 2 ft x 3 ft grates
- three standard 2 ft x 2 ft grates
- one 3 ft x 5 ft grate

Design will ordinarily use a standard dimension such as W = 2 ft. Note the increase when blockage is anticipated.

Flanking Inlets: Mitigation Against Clogging and Blockage

Sags are natural accumulation points for debris, and therefore blockage should be accounted for. Blockage reduces inlet capacity by reducing flow perimeter under weir conditions and open area under orifice conditions. In such cases, flanking inlets short distances away from the sag grate or curb inlets should be considered as mitigation against blockage. The purpose of the flanking inlets is to act in relief of the inlet at the low point if it should become clogged or if the design spread is exceeded. While they may also provide additional system capacity when the sag is not blocked, this is not the design intent.

Flanking inlets can be located so they will function before water spread exceeds the allowable spread T at the sag location. They should be located to that they receive all of the flow when the primary sag inlet is clogged, without exceeding the design spread in the sag. If the flanking inlets are the same dimensions as the primary (sag) inlet, they will each intercept one-half the design flow when they are located such that the ponding depth d_{2f} at the flanking inlets is 63% of the ponding depth d_2 at the low point (i.e., when the flanking inlets are $0.37d_2$ higher than the sag). Regardless of the calculation results, the flanking inlets should be at least 4 in (100 mm) higher in elevation than the sag low point. If the flanking inlets are not the same size as the primary inlet, it will be necessary to either develop a new factor or do a trial-and-error solution using assumed depths with the weir equation to determine the capacity of the flanking inlet at the given depths.

Vertical curves are characterized by the curvature rate factor K:

$$K = L/(S_2 - S_1)$$

where K = vertical curve rate, ≤ 165 ft/% (50 m/%) for drainage evaluation
L = length of vertical curve (ft)
S = approach grades in percent

Spacing from the sag is calculated as

$$x = \{200(\Delta d)K\}^{0.5}$$

where Δd = difference between ponding depths at sag and flanking inlets = $d_2 - d_{2f} = 0.37d_2$, x and Δd in consistent units.

AASHTO geometrics policy specifies maximum K values for various design speeds and a maximum K = 165 ft/% (50 m/%) considering drainage.

Example: Locate Flanking Inlets

A 490 ft sag vertical curve has beginning and ending slopes of –2.5% and +2.5%, respectively. Maximum allowable spread T is 10 ft. Locate flanking inlets to accommodate a completely clogged sag inlet. Assume a constant cross-section slope, $S_x = 0.02$.

Rate of curvature: $K = L/(S_{end} - S_{beg}) = 490 \text{ ft}/(2.5 - {}^{-}2.5) = 98 \text{ ft}/\%$

Water depth at curb in sag: $d_2 = S_xT = (0.02)(10) = 0.2$ ft

Depth at flanking locations (assume flanking inlets same size as primary):

d_{2f} = 63% of sag depth = $(0.63)(0.2) = 0.126$ ft

Calculate spacing: $x = \{200(\Delta d)K\}^{0.5} = \{200 \text{ x } (0.2 - 0.126) \text{ x } 98\}^{0.5} = 38$ ft

Flanking inlet dimensions: same as sag inlet (assumed; and required for 0.63 factor)

12-5.03 Hydraulic Analysis of Closed Systems

12-5.03.1 Introduction

A closed drainage system is one in which storm water runoff is conveyed by underground pipes as opposed to open roadside ditches. Pavement runoff is introduced to the system via catch basins and inlets. Off-pavement runoff might enter through stub connections to pipes and catch basins or as flow onto the pavement. The runoff is ultimately discharged to a natural drainage course or stream, or a swale in the adjacent fields or woods. The system pipes generally run laterally along both sides of the road. Depending on the particular site conditions, cross-pipes may carry water from one side of the road to the other. The lateral pipes are commonly “type C underdrain”, perforated pipe with the perforations up. These pipes, in addition to carrying stormwater, also drain the subbase. Closed system cross-pipes are non-perforated.

Basic Design Controls:

1) size pipe for just-full free-surface flow (i.e., not pressurized)
2) average velocity in pipe should be between 2 ft/s (0.6 m/s) and 15 ft/s (4.5 m/s)
3) pipe should follow profile grade, maintaining a slope of at least 0.003 ft/ft
4) system should ultimately discharge to a free outfall
5) maintain a 3 in (75 mm) difference in elevation between inlet pipes and outlet pipe in a catch basin
6) in the presence of other underground utilities, potential conflicts should be assessed on the basis of pipe outside diameter
7) calculations should be performed for both smooth and corrugated pipe

In addition to these considerations, the designer should also refer to guidelines under “Drainage Appurtenances”.

In the sections that follow, a simplified procedure is given here that accomodates backwater effects and minor losses at pipe junctions and other structures. Controls (3) and (4) above (slope and free outfall) are intended to prevent backwater; control (5) above (invert differentials) is intended to account for minor losses due to changes in size and direction at manholes and catch basins. Hydraulic engineering staff or the Hydrology Unit should be consulted when these design controls cannot be maintained and surcharging under design conditions is suspected.

12-5.03.2 Hydraulics of Fully Flowing Circular Pipes

Manning's equation for open channel flow is

$$v = \lambda R_h^{2/3} S^{1/2}/n$$

where v = velocity (m/s)
λ = unit conversion factor (1.486 for U.S. Customary; 1 for metric)
R_h = hydraulic radius (ft or m) = A/P; A = flow area and P = wetted perimeter
S = slope (dimensionless; ft/ft or m/m)
n = Manning's roughness

For just-full flow (i.e., depth of flow equals pipe diameter) in a circular pipe:

$A = \pi D^2/4$ (circular flow area)
$P = \pi D$ (wetted circular perimeter)

and

$$v = \lambda\{1/(4^{2/3}n)\}D^{2/3}S^{1/2} = \lambda(0.397/n)D^{2/3}S^{1/2} \quad \text{(ft/s or m/s)}$$
$$Q = Av = \lambda(\pi/4^{5/3})D^{8/3}S^{1/2}/n = \lambda(0.312/n)\, D^{8/3}S^{1/2} = k(D)S^{1/2} \quad (\text{ft}^3\text{/s or m}^3\text{/s})$$

The quantity k(D) (= $Q/S^{1/2} = \lambda(0.312/n)\, D^{8/3}$) is known as the conveyance function and depends on pipe characteristics (diameter and roughness) only.

For a known flow Q, the pipe diameter that just accommodates this flow under non-pressurized (fee-surface) conditions can be calculated:

$$D = \{4^{5/3}nQ/\lambda\pi S^{1/2}\}^{3/8} = (1.55/\lambda^{3/8})\{nQ/S^{1/2}\}^{3/8} \quad \text{(ft or m)}$$

These various forms of Manning's equation for flow in circular pipe are summarized in Figures 12-5.4 and 12-5.5 in dimensionless form. The geometric and conveyance functions are tabulated in Table 12-5.3.

Example: Determine the discharge through a fully flowing 18 in (450 mm) corrugated metal pipe on a slope of 0.02.

Since corrugated metal is specified, n = 0.025 is an acceptably conservative estimate. From Table 12-5.3 or Figure 12-5.5, conveyance k = 55. The discharge $Q = kS^{1/2} = (55)(0.02)^{1/2} = 7.8$ ft^3/s.

Table 12-5.5
Circular Pipe Geometric and Conveyance Functions

				Conveyance k (ft^3/s)			
Diam D (in)	**Area A (ft^2)**	**Perim P (ft)**	**Hydraulic Radius R_h (ft)**	**n = 0.010**	**n = 0.015**	**n = 0.020**	**n = 0.025**
6	0.196	1.571	0.125	7.3	4.9	3.7	2.9
12	0.785	3.142	0.250	46.4	30.9	23.2	18.5
18	1.767	4.712	0.375	136.7	91.1	68.4	54.7
24	3.142	6.283	0.500	295	196	147	118
30	4.909	7.854	0.625	534	356	267	214
36	7.069	9.425	0.750	868	579	434	347
42	9.621	10.996	0.875	1310	873	655	524
48	12.566	12.566	1.000	1870	1247	935	748
54	15.904	14.137	1.125	2560	1707	1280	1024
60	19.635	15.708	1.250	3391	2261	1696	1356
66	23.758	17.279	1.375	4372	2915	2186	1749
72	28.274	18.850	1.500	5515	3676	2757	2206
78	33.183	20.420	1.625	6827	4551	3413	2731
84	38.485	21.991	1.750	8319	5546	4159	3327
90	44.179	23.562	1.875	9999	6666	5000	4000
96	50.265	25.133	2.000	11877	7918	5939	4751
102	56.745	26.704	2.125	13962	9308	6981	5585
108	63.617	28.274	2.250	16261	10840	8130	6504
114	70.882	29.845	2.375	18783	12522	9391	7513
120	78.540	31.416	2.500	21536	14358	10768	8615

Notes: for Manning's equation in fully flowing circular pipe (ft or m and sec):

$v = \lambda R_h^{2/3} S^{1/2}/n$

$A = \pi D^2/4$

$P = \pi D$

$R_h = D/4$

$k = \lambda(\pi/4^{5/3})D^{8/3}/n = (0.312\lambda/n)\, D^{8/3}$; $\lambda = 1$, metric; 1.486, U.S. Customary

$Q = kS^{1/2}$

Figure 12-5.4: Circular Pipe Full Flow Geometric Functions

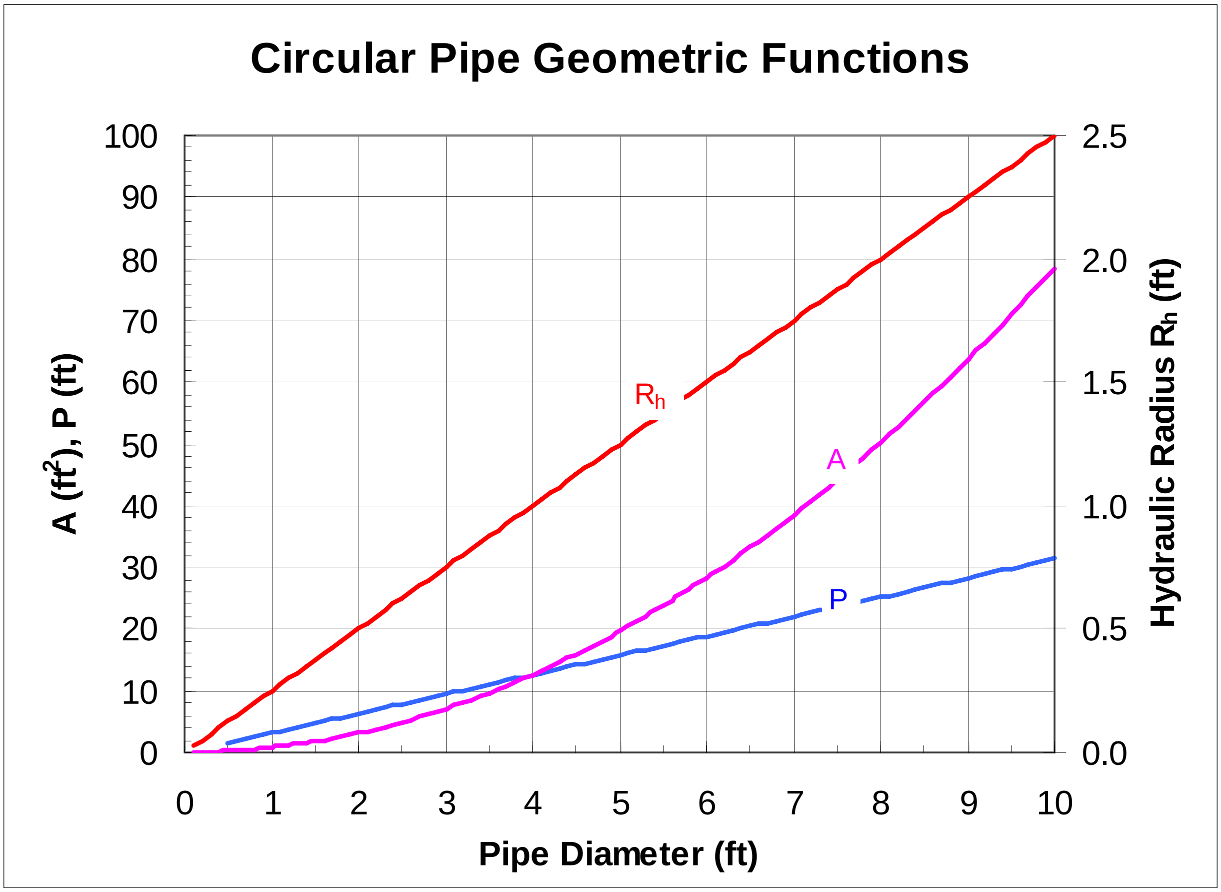
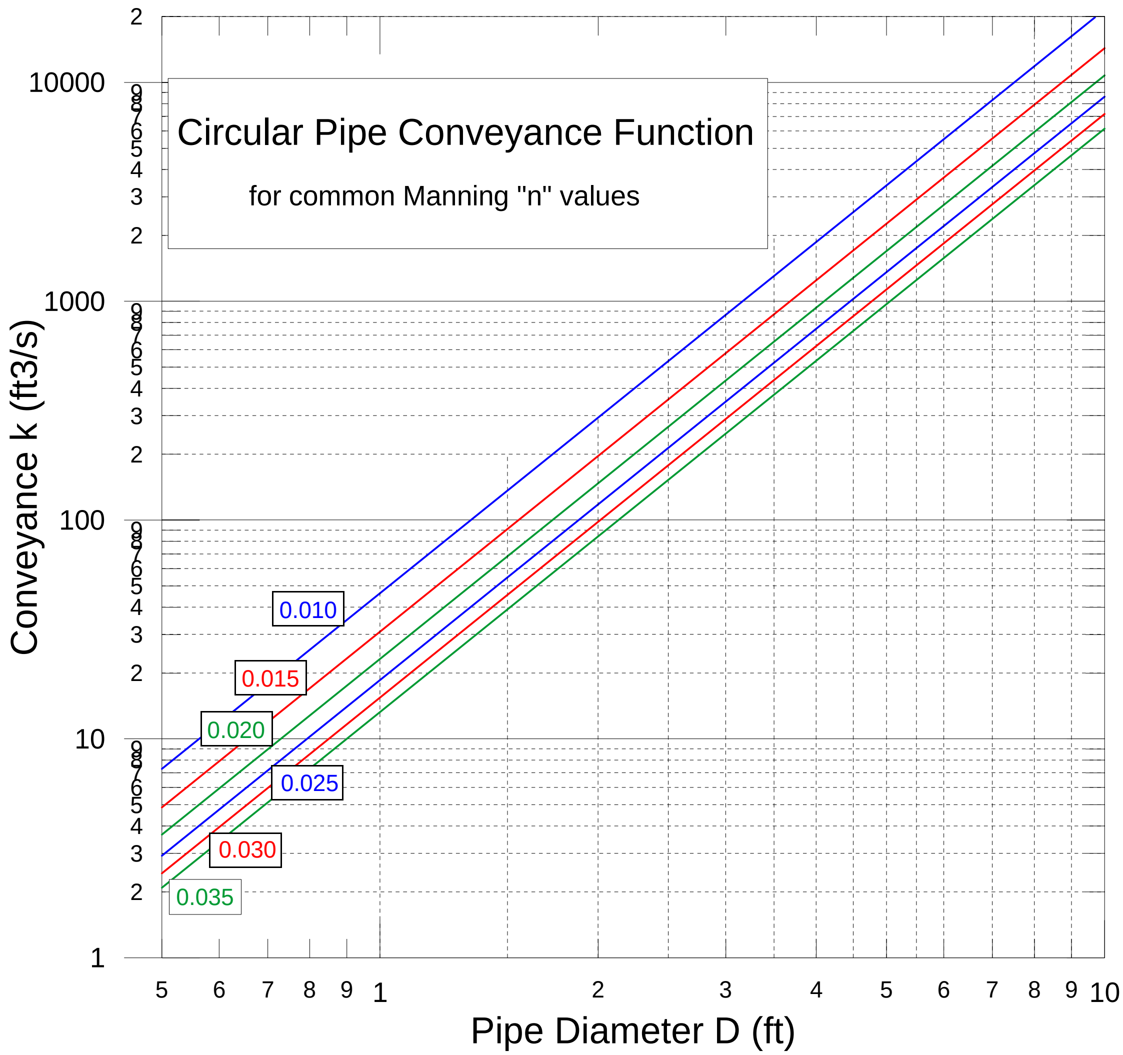


Figure 12-5.5: Circular Pipe Conveyance Function



12-5.03.3 Hydraulics of Partially Flowing Circular Pipes

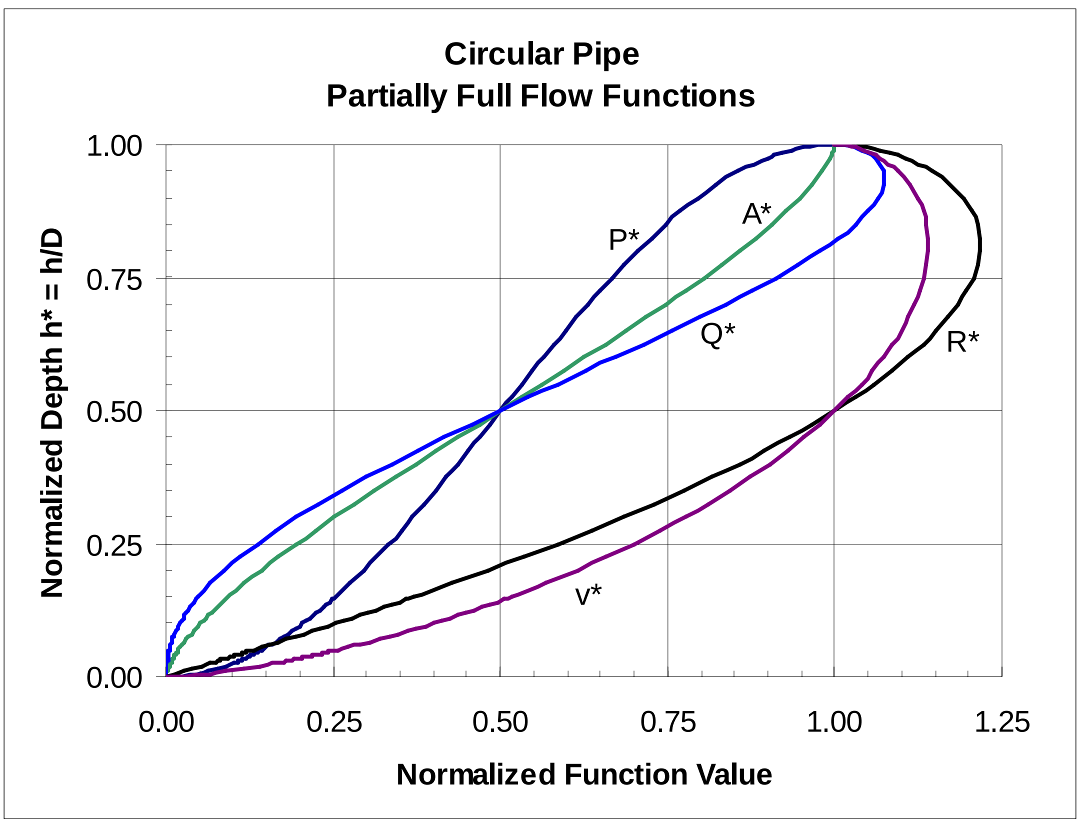
Occasionally it is necessary to consider pipes flowing partially full. Partial flow is best approached through scaled, dimensionless quantities as defined in Table 12-5.4. Figure 12-5.6 shows the dimensionless partial flow functions; analysis can also be done using the equations in Table 12-4.18. These values can be converted to values for pipes of specific size by simple scaling. A dimensionless quantity is the partial flow quantity divided by the corresponding quantity of a full-flowing pipe of specified size.

Table 12-5.6: Dimensionless Quantities for Partially Flowing Pipes

Dimensionless Quantity	Symbol	Definition	Equation for Partial Quantity
Depth	h^*	h/D	$H = Dh^*$
Flow Area	A^*	A/A_f	$A = A_fA^*$
Wetted Perimeter	P^*	P/P_f	$P = P_fP^*$
Hydraulic Radius	R_h^*	$R_h/R_{h\,f}$	$R_h = R_{h\,f}R_h^*$
Flow	Q^*	Q/Q_f	$Q = Q_fQ^*$

Notes: "*" = dimensionless quantity; "f" = full flowing quantity

Figure 12-5.6: Functions for Partially Flowing Pipes



Example: Flow in Partially Full Pipe A 24 in (600 mm) pipe, S = 0.001 and n = 0.021, flows 75% full (by depth). Determine the geometric quantities and the flow in the partially full pipe.

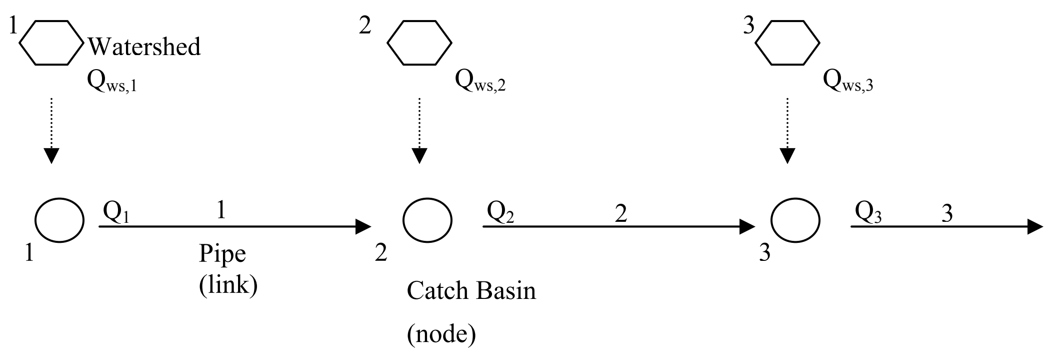
$h^* = h/D = 0.75 \Rightarrow h = (.75)(24 \text{ in}) = 18 \text{ in} =$ depth of flow
$A_f = \pi(2)^2/4 = 3.142 \text{ ft}^2$; $A^* = 0.805 \Rightarrow A = A_f A^* = (3.142)(0.805) = 2.53 \text{ ft}^2$
$P_f = \pi(2) = 6.283 \text{ ft}$; $P^* = 0.667 \Rightarrow P = P_f P^* = (6.283)(0.667) = 4.19 \text{ ft}$
$R_{hf} = (2)/4 = 0.5 \text{ ft}$; $R_h^* = 1.207 \Rightarrow R_h = R_{hf} R_h^* = (0.5)(1.207) = 0.60 \text{ ft}$
$Q_f = kS^{1/2} = (147)(0.001)^{1/2} = 4.65 \text{ ft}^3/\text{s}$; $Q^* = 0.912 \Rightarrow Q = Q_f Q^* = (4.65)(0.912) = 4.25 \text{ ft}^3/\text{s}$
$v = Q/A = 1.68 \text{ ft/s}$

12-5.03.4 Conceptual Model for Closed System Design

The usual objective in closed system design is to determine pipe sizes that convey specified design flows, subject to a variety of system and design policy constraints. The general procedure is to estimate the peak flow Q (typically the ten-year flow, Q_{10}) using hydrologic methods already described. Closed systems usually drain small areas and so the Rational Method will most often be the hydrologic tool of choice. The pipe size is calculated using Manning's equation and the peak flow estimate from hydrologic analysis.

Closed drainage systems for road projects are generally simpler than municipal storm water systems, in that branching is minimal. A closed system consists of small runoff-generating areas (watersheds) connected by pipes. The system is modeled as an assemblage of links (the pipes) and nodes (junctions, primarily catch basins), as shown in Figure 12-5.7.

Figure 12-5.7: Schematic of Closed System



Water is only allowed to enter the system at nodes, usually via inlets or stub pipes to catch basins. Water moves through the system in links (the pipes). The system is assumed to start at the upgradient end with a node and terminate at the downgradient end with a pipe. Every node has an associated composite watershed and a single associated outlet pipe; the node constitutes the outlet point of the composite watershed. This composite consists of two kinds of subwatersheds:

1) Those connected to a node via inlet pipes from upgradient nodes
2) Those that drain directly to a catch basin, e.g., by an inlet or stub connection

The total flow into a node determines the size of the outlet pipe. Every pipe in the system is sized to pass flows with the same return period (usually 10 years).

For example, in the schematic above, the total composite watershed at node 2 consists of subwatershed 1 and subwatershed 2. Watershed area and flow path length increase as one moves downgradient through the system. Thus, time of concentration t_c increases as one moves down through the system. When the Rational Method is used to estimate design flows, this means that the design storm duration increases and the design storm intensity decreases from the first to last node.

Pipe sizes are determined by combining peak flow estimates with equations of mass (water) balance and simple Manning's equation hydraulics. In applying the equations, all quantities are assumed known except for the pipe size. Analysis always proceeds sequentially from the uppermost initial node to the final system outlet pipe.

Mass balance requires that the total water entering a node must equal (balance) the water leaving. In most cases there is a single entering pipe, a single subwatershed direct contribution through an inlet, and a single outlet pipe. For a simple non-branching system, the nodes, pipes and subwatersheds are organized sequentially as 1, 2, … N. Node 1 is the uppermost node; pipe N is the system outlet. The flow Q_i is the flow exiting node i in pipe i; this flow Q_i enters node i+1 as the inlet pipe. The subwatershed runoff $Q_{ws,i}$ enters node i directly through the catch basin inlet. The total flow $Q_{in,i}$ entering node entering node i is the sum of all pipes entering node i and all subwatersheds draining directly to node i. The mass balance equation for the i-th node is

$$\begin{aligned} \text{Flow Out} &= \text{Flow In} \\ Q_i &= Q_{i-1} + Q_{ws,i} = Q_{in,i} \end{aligned}$$

For example, referring to the figure above, $Q_2 = Q_1 + Q_{ws,1}$. The flow terms Q_{i-1} and $Q_{ws,i}$ are known from the hydrology. The outlet flow Q_i (known, equal to total flow in) is written in terms of the unknown pipe size D_i (pipe leaving node i) using Manning's equation:

$$Q_i = (\lambda\pi/4^{5/3})D_i^{8/3}S^{1/2}/n = Q_{in,i} \quad (\text{ft}^3/\text{s or m}^3/\text{s})$$

$$D_i = 16\{nQ_i/S^{1/2}\}^{3/8} \quad (\text{inches})$$

One the pipe size is calculated, the velocity should be calculated using Manning's equation and checked against the allowable range of values (2 – 15 ft/s; 0.6 – 4.5 m/s) in order to protect against excessive abrasion. Velocity can be increased by increasing the slope or decreasing the pipe size. Increasing the slope will necessitate reducing the elevation of all downstream structures and/or raising the elevation of all upgradient structures, options often not available due

to site constraints. Hydraulic engineering staff or the Hydrology Unit should be consulted if acceptable velocities cannot be obtained using the simplified method outlined here.

12-5.03.5 Rational Method for Closed System Design

Using the Rational Method to estimate design flows to a catch basin (node), the design storm duration t_r is set equal to the watershed time of concentration. For any steady rainfall intensity i, peak flow will occur when the entire watershed is contributing runoff at the outlet; rain must persist for a duration at least equal to the time of concentration t_c for this to occur. The time of concentration t_c is the time for a raindrop falling on the hydraulically most distant point in the watershed to reach the outlet. However, according to the rainfall IDF curve (Figure 12-2.1), average intensity decreases as duration increases. Thus, design peak flow is obtained when storm duration is just equal to the time of concentration. When $t_r < t_c$, the entire watershed is not contributing; when $t_r > t_c$, the entire watershed is contributing but at reduced intensity. In a closed system, the time of concentration must be determined independently at each node for the total composite watershed draining to that node.

The Rational Method assumption that peak flow is obtained when storm duration just equals time of concentration is not always justified. In particular, watersheds with a significant impervious fraction near the outlet may peak at a time less than the total watershed time of concentration. This is particularly problematic when the remainder of the watershed has a natural land cover, or generally when the watershed displays runoff coefficient variability. This may indicate that rainfall-runoff modeling is the more appropriate method for determining peak flows. Staff hydraulic engineers or the Hydrology Unit should be consulted in such instances.

At each node (catch basin) in a closed system, there is a finite number of flow paths that might qualify as hydraulically longest. Each pipe entering a node marks the path draining from an upgradient node and associated watershed; the other possibilities are the hydraulically longest flow paths in subwatersheds draining directly to the node. For a pipe entering node i, the corresponding time of concentration is the time of concentration $t_{c,i-1}$ to the node (i-1) immediately upgradient plus the time in pipe $t_{t,i-1}$ between nodes (i-1) and i. For a subwatershed draining directly to node i, t_c (= $t_{ws,i}$ below) is calculated using the TR-55 conceptual model already presented. The travel time in pipe (t_t) is calculated using Manning's equation:

t_t (min) = L/60v , where L = pipe length (ft) and v = velocity (ft/s)

As a practical matter, the pipe travel time t_t is usually much smaller than the subwatershed t_c. Among the candidate times of concentration, the maximum is chosen. For example, at node 3 in the schematic above

$$t_{c3} = \text{maximum} \{ t_{c2} + t_{t2} \, ; t_{ws,3} \}$$

The maximum value is chosen to insure that the entire composite watershed is contributing. This equation is easily generalized to multiple direct-draining watersheds and multiple inlet pipes and their associated upgradient watersheds.

12-5.03.6 Computational Procedure

Calculations for closed system design are best performed using dedicated software or specially prepared spreadsheets. The general computational sequence will be outlined here for the occasional time when manual calculation might be preferred. Included in this sequence are the basic steps of the Rational Method for closed system design. Note that diameter D, hydraulic radius R_h, and flow depth h are calculated in (in), and intensity i in (in/hr). Conversion factors are built into the calculations.

The basic computational algorithm assumes no more than two watersheds draining to a catch basin. When two watersheds drain to a catch basin, one watershed is assumed to drain via an inlet pipe and the other enters directly without specifying a particular inlet device. The objective is to size the basin outlet pipe. Cases of more than two watersheds entering a basin can be addressed by a simple extension of the basic algorithm. Detailed step-by-step calculations are presented in Table 12-5.5, the manual calculation analog to the Excel worksheet template in Figure 12-5.8.

1) Gather all watershed and system data and make initial assumptions regarding pipe invert elevations, lengths, slopes, roughnesses, etc.
2) Create a link-node diagram of the system. Number the diagram components and label the diagram with pertinent data.

Starting at node (catch basin) 1 and working sequentially downgradient towards the outlet, for the i-th node

3) Determine $t_{c,i}$ at node i using the TR-55 method and Manning's equation for pipe travel time $t_{t,i-1}$

   $$t_{c,i} = \max\{ t_{c,i-1} + t_{t,i-1} \,;\, t_{ws,i} \}$$

4) Determine design storm intensity i for duration $t_r = t_c$ (Figure 12-2.1)
5) Calculate weighted runoff coefficient C for composite watershed at node i
6) Calculate peak flow using Rational Equation: $Q = \mu CiA$ (ft^3/s)
7) Calculate pipe size to accommodate design flow Q:
   $D = 16\{nQ/S^{1/2}\}^{3/8}$ (in) $D = 1.34\{nQ/S^{1/2}\}^{3/8}$ (ft)
8) Round D (in) to next available size and check for feasibility
9) Check velocity against acceptable limits: v (ft/s) $= 0.59D^{2/3}S^{1/2}/n$ (D in ft)

These steps are formalized in Figure 12-5.8 (a MS-Excel worksheet; calculations proceed from bottom to top), with instructions for each calculation in the corresponding computation template in Table 12-5.6. While these calculations can be performed manually, it is recommended that the worksheet be used, in which case the calculations are performed automatically after basic data has been input. This manual does not give detailed instructions for using the worksheet, since future modifications are likely. Interested users should contact the Hydrology Section.

Table 12-5.6 provides additional instructions for manual calculations. The numbered rows in the table correspond to the rows in the worksheet. For computational and organizational reasons, the order of the rows in the worksheet and table are slightly different near the end of the calculations. Referring to Table 12-5.6, items labeled “D” are data entry items; some items that are calculated (“C”) in the worksheet would probably be evaluated by look-up (“L”) in the appropriate charts (Figures 12-2.1 and 12-5.6).

This algorithm applies directly to non-branching networks that proceed from the most upgradient catch basin through a sequence of catch basins to the outlet. Branching networks require a small adjustment. Again, start with the most upgradient node, but pause the analysis at the first branch point encountered. On the other branching stem above this node, proceed from the uppermost node to the branch point. Repeat for any other stems that outlet to the branch node. These composite watersheds that outlet to branch node are then treated as single incremental watersheds draining directly to the branch node. Analysis then proceeds in the usual manner until another branch node is encountered and the process is repeated. This is illustrated in the example that follows. Branching to three or more stems requires a further modification. This is discussed following the example.

Table 12-5.7a: Template for Closed System Design by Manual Calculation

	Item	Source	Variable	Notes
1	Watershed ID	D	Identifier	From layout
2	From station	D	x_0 (ft or m)	From layout
3	To station	D	x_1 (ft or m)	From layout
4	Length	C	$x_1 - x_0$ (ft or m)	
5	Invert Elev Upper end	D	z_0 (ft or m)	From layout
6	Invert Elev Lower End	D	z_1 (ft or m)	From layout
7	Slope	C	$(x_1\text{-}x_0)/(z_1\text{-}z_0)$ (ft/ft or m/m)	
8	Time of Conc	D	T_c (min) for incremental area	From hydrology
9	Incremental Area	D	A_{inc} (ac or km^2)	From hydrology
10	Total Time of Concentration	C	T_c (min)	Max T_c {all subwatersheds draining into catch basin}
11	Total area A_{tot}	C	$A_{tot} = A_{prev} + A_{inc}$ (ac or km^2)	Sum previous and incremental areas
12	Incremental Rational C	D	C	From hydrology
13	Cumulative Weighted C	C	$\Sigma A_i C_i / A_{tot}$	For total area draining to CB
14	Rainfall Rate	C/L	i_{10} (in/hr or mm/hr)	10-yr intensity; Fig 12-2.1
15	Runoff Direct	C	$Q = \mu CiA$ (ft^3/s or m^3/s)	Rational Equation
16	Runoff Offsite	D	Q_{off} (usually 0)	Additional runoff source
17	Runoff total	C	$Q_{tot} = Q + Q_{off}$	Total runoff to catch basin
18	Manning roughness n	D	N	CMP 0.025; plastic 0.012
19	Flow depth fraction	D	Target $h/D \leq 1$	Usually = 1
20	Pipe Diam	C	$D = (1.55\alpha/\lambda^{3/8})\{nQ/S^{1/2}\}^{3/8}$ (in or mm)	Exact solution
21	Pipe Diam (design)	C	D (in or mm) & (ft or m)	Design: round to next size
22	Pipe Area (full)	C	$A_f = \pi(D/4)^2$ (ft^2 or m^2)	
23	Hydraulic Radius (full)	C	$R_{h,f} = D/4$ (ft or m)	
24	Pipe Full Velocity	C	$v_f = \lambda(R_h)^{2/3}S^{1/2}/n$ (ft/s or m/s)	Manning's equation
25	Pipe Full Capacity	C	$Q_f = A_f v_f$ (ft^3/s or m^3/s)	
26	Percent of Full Capacity	C	$Q^* = Q_{tot}/Q_f$	
27	Flow Depth Fraction	C/L	h^* (look-up against Q^* value)	Fig 12-5.6
28	Flow depth	C	$h = h^* D$ (in or mm)	
29	Velocity	C/L	$v^* \Rightarrow v = v^* v_f$ (look up v^* against h^*)	Fig 12-5.6
30	Travel time in pipe	C	$T_t = L/60v$ (min)	

Note: U.S. Customary Units: $\alpha = 12$, $\lambda = 1.486$, $\mu = 1$; *metric:* $\alpha = 1000$, $\lambda = 1$, $\mu = 0.28$

Source: D = specified data; C = calculation; L = look-up

Table 12-5.7b: Template for Closed System Design by Manual Calculation

	Item	Source	Variable	Value
1	Watershed ID	D	Identifier	
2	From station	D	x_0 (ft or m)	
3	To station	D	x_1 (ft or m)	
4	Length	C	$x_1 - x_0$ (ft or m)	
5	Invert Elev Upper end	D	z_0 (ft or m)	
6	Invert Elev Lower End	D	z_1 (ft or m)	
7	Slope	C	$(x_1\text{-}x_0)/(z_1\text{-}z_0)$ (ft/ft or m/m)	
8	Time of Conc	D	T_c (min) for incremental area	
9	Incremental Area	D	A_{inc} (ac or km^2)	
10	Total Time of Concentration	C	T_c (min)	
11	Total area A_{tot}	C	$A_{tot} = A_{prev} + A_{inc}$ (ac or km^2)	
12	Incremental Rational C	D	C	
13	Cumulative Weighted C	C	$\Sigma A_i C_i / A_{tot}$	
14	Rainfall Rate	C/L	i_{10} (in/hr or mm/hr)	
15	Runoff Direct	C	$Q = \mu CiA$ (ft^3/s or m^3/s)	
16	Runoff Offsite	D	Q_{off} (usually 0)	
17	Runoff total	C	$Q_{tot} = Q + Q_{off}$	
18	Manning roughness n	D	N	
19	Flow depth fraction	D	Target $h/D \leq 1$	
20	Pipe Diam	C	$D = (1.55\alpha/\lambda^{3/8})\{nQ/S^{1/2}\}^{3/8}$ (in or mm)	
21	Pipe Diam (design)	C	D (in or mm) & (ft or m)	
22	Pipe Area (full)	C	$A_f = \pi(D/4)^2$ (ft^2 or m^2)	
23	Hydraulic Radius (full)	C	$R_{h,f} = D/4$ (ft or m)	
24	Pipe Full Velocity	C	$v_f = \lambda(R_h)^{2/3}S^{1/2}/n$ (ft/s or m/s)	
25	Pipe Full Capacity	C	$Q_f = A_f v_f$ (ft^3/s or m^3/s)	
26	Percent of Full Capacity	C	$Q^* = Q_{tot}/Q_f$	
27	Flow Depth Fraction	C/L	h^* (look-up against Q^* value)	
28	Flow depth	C	$h = h^* D$ (in or mm)	
29	Velocity	C/L	$v^* \Rightarrow v = v^* v_f$ (look up v^* against h^*)	
30	Travel time in pipe	C	$T_t = L/60v$ (min)	

Note: *U.S. Customary Units:* $\alpha = 12$, $\lambda = 1.486$, $\mu = 1$; *metric:* $\alpha = 1000$, $\lambda = 1$, $\mu = 0.28$

Source: D = specified data; C = calculation; L = look-up

Figure 12-5.8: Worksheet Template for Design of Closed Systems

Closed System Worksheet - Preliminary Design of Simple Systems

Start data entry from bottom; enter data in blue cells only.

Units: US (US or metric)
Design Event: 10 -Year

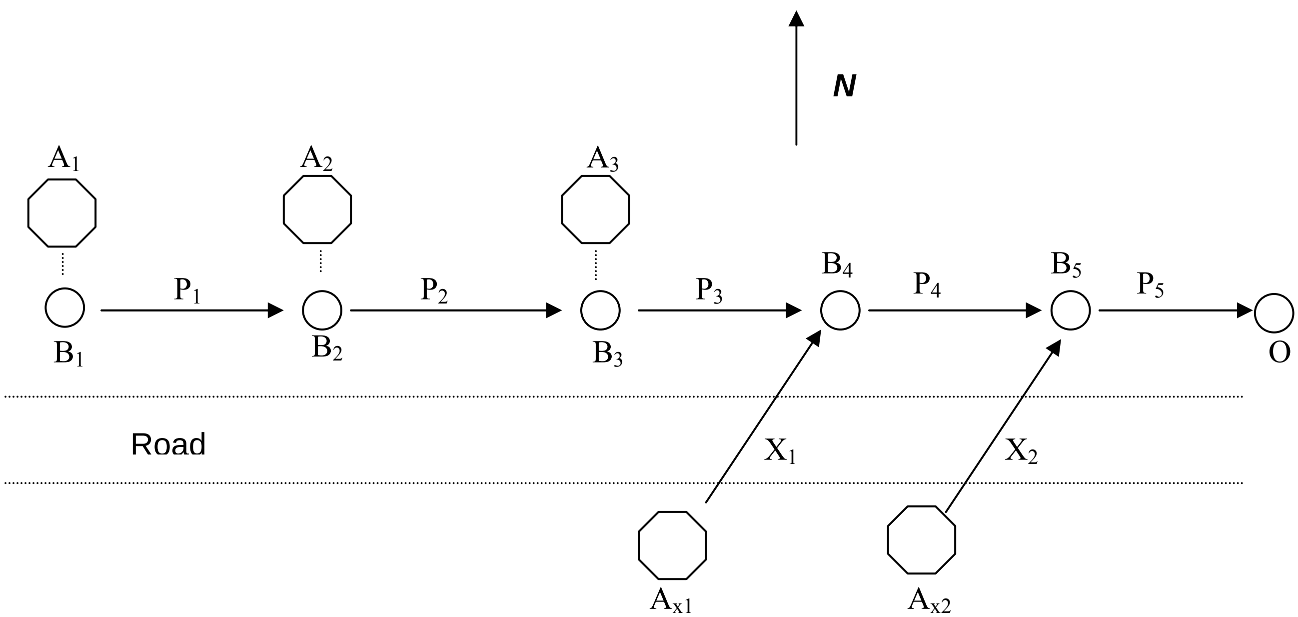
	Design of Closed System	Partial Flow	30	Time in Pipe Section	min											
			29	Velocity (design) =V	ft/s											
			28	Flow Depth (design)	in											
			27	Flow Depth Fraction (design)												
			26	Percent of Capcity Q_F												
Pin #		Full Flow	25	Pipe-full Capacity Q_F	ft3/s											
			24	Pipe-Full Velocity V_F	ft/s											
			23	Hydraulic Radius	ft											
			22	Pipe Area	ft2											
		Pipe Design	21	***Pipe Diam (design)***	***in***											
			20	Pipe Diam (exact)	in											
			19	Flow Depth Fraction (nom)		1										
			18	Manning Roughness Coeff = n		0.013										
	Runoff Calculation		17	Runoff Total (design) Q_T	ft3/s											
			16	Runoff Offsite = Q_{off}	ft3/s											
			15	Runoff Direct Q = µCiA	ft3/s											
			14	Rainfall Rate I	in/hr											
			13	Cum Wt'ed C												
			12	Total Area =A_T	ac											
			11	Total T_c (min)	min											
			10	Incremental Rational Coeff=C												
			9	Incremental Area A_I	ac											
			8	Time of Conc T_c	min											
	System	Topography	7	slope S	ft/ft											
			6	Inv Elev Lower End	ft											
			5	Inv Elev Upper End	ft											
			4	Length (m)	ft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Project:		Location	3	To Station (lower)	ft											
			2	From Station (upper)	ft											
			1	CB/Node												

Precip Station	1	(Portland-1/Eastport-2/Rangely-3/
Event Return Period (yrs)	10	Presque Isle-4/Newport-5/Millinocket-6)

Units	US	(US or metric)

Example: Closed System Design

The watershed system schematic was constructed from the watershed delineation and proposed pipe layout. Along the north side of the road there are 3 subwatersheds in series from east to west, A_1, A_2, and A_3. A_1 directly feeds pipe P_1; A_2 and pipe P_1 (watershed A_1) feed catch basin B_2 from which exits pipe P_2; etc. On the south side of the road are two individual subwatersheds (A_{x1} and A_{x2}) that cross the road through cross-pipes X_1 and X_2. The catch basins may be real physical entities or may just serve as conceptual nodes in the system model. The watershed area draining to a catch basin (node) increases as one moves toward the eventual outlet O (not a real catch basin). This system is not just a simple serial configuration, though, as it branches at basins B_5 and B_4 (branching is best seen by starting at the outlet and working upgradient).



Analysis always proceeds from the most upgradient subwatershed towards the outlet. When a branch node is reached (e.g., B_4), all subwatersheds and pipes upgradient of the node have to be analyzed before proceeding.

In the attached Excel worksheet in Figure 12-5.9, data entry starts in the bottom row and works upwards. Immediately below the system design area, the representative IDF curve (Figure 12-2.1) is specified once. The entries and calculations for catch basin B_2 and pipe P_2 proceed as follows. Note that the composite watershed draining to B_2 consists of two subwatersheds, A_1 and A_2. A_1 is assumed to enter B_2 through inlet pipe P_1 that has been previously sized; A_2 is assumed to drain directly to B_2.

Figure 12-5.9: Worksheet Template, Closed System Design Example

Closed System Worksheet - Preliminary Design of Simple Systems

Start data entry from bottom; enter data in blue cells only.

Units: **US** (US or metric)
Design Event: **10** -Year

Project: MDOT Drainage Manual Example
Pin # 9999.99
1/6/2004

Section	Row	Item	Units											
Design of Closed System – Partial Flow	30	Time in Pipe Section	min	1.1	0.3	0.5		0.1		0.6		0.1		0.5
	29	Velocity (design) =V	ft/s	3.9	10.9	10.0		7.1		6.8		7.8		8.0
	28	Flow Depth (design)	in	18	19	24		8		29		8		29
	27	Flow Depth Fraction (design)		0.67	0.72	0.71		0.68		0.70		0.57		0.73
	26	Percent of Capcity Q_F		79	87	86		80		84		61		89
Design of Closed System – Full Flow	25	Pipe-full Capacity Q_F	ft3/s	13.9	38.6	52.89		5.04		58.09		9.14		58.38
	24	Pipe-Full Velocity V_F	ft/s	3.5	9.7	8.9		6.4		6.0		7.4		7.0
	23	Hydraulic Radius	ft	0.56	0.56	0.69		0.25		0.88		0.31		0.81
	22	Pipe Area	ft2	3.98	3.98	5.94		0.79		9.62		1.23		8.30
Design of Closed System – Pipe Design	21	***Pipe Diam (design)***	***in***	***27***	***27***	***33***		***12***		***42***		***15***		***39***
	20	Pipe Diam (exact)	in	25	26	31		11		39		12		37
	19	Flow Depth Fraction (nom)		1	1	1	1	1	1	1	1	1	1	1
	18	Manning Roughness Coeff = n		0.013	0.013	0.013	0	0.013	0	0.013	0.013	0.013	0	0.013
Runoff Calculation	17	Runoff Total (design) Q_T	ft3/s	11.0	33.4	45.4		4.051		48.725		5.597		51.879
	16	Runoff Offsite = Q_{off}	ft3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	15	Runoff Direct Q = µCiA	ft3/s	11.0	33.4	45.4		4.051		48.725		5.597		51.879
	14	Rainfall Rate I	in/hr	3.9	3.7	3.5		3.5		3.4		4.8		3.4
	13	Cum Wt'ed C		0.40	0.58	0.51		0.44		0.50		0.33		0.48
	12	Total Area =A_T	ac	7.0	15.8	25.70		2.6000		28.3000		3.5000		31.8000
	11	Total T_c (min)	min	12.00	14.20	16.00		15.30		16.50		6.70		17.05
	10	Incremental Rational Coeff=C		0.4	0.72	0.40		0.44		0.50		0.33		0.48
	9	Incremental Area A_I	ac	7.0	8.8	9.90		2.6000		28.3000		3.5000		31.8000
	8	Time of Conc T_c	min	12.0	14.2	16.0		15.3		16.5		6.7		17.1
System – Topography	7	slope S	ft/ft	0.0020	0.0156	0.0100		0.0200		0.0033		0.0200		0.0050
	6	Inv Elev Lower End	ft	107.50	103.50	100.00		100.00		99.00		99.00		97.50
	5	Inv Elev Upper End	ft	108.00	107.00	103.00		100.50		99.75		99.50		98.75
	4	Length (m)	ft	250.00	225.00	300.00	##	25.00	0.00	225.00	0.00	25.00	##	250.00
Location	3	To Station (lower)	ft	250	475	775		25		1000		25		1250
	2	From Station (upper)	ft	0	250	475		0		775		0		1000
	1	CB/Node		B1	B2	B3		Ax1		B4		Ax2		B5

Precip Station	1	(Portland-1/Eastport-2/Rangely-3/ Presque Isle-4/Newport-5/Millinocket-6)
Event Return Period (yrs)	10	

Units: US (US or metric)

Design of pipe P_2 by manual calculation is illustrated in Table 12-5.6. This discussion will also assist in using the worksheet template; blank forms (Figure 12-5.8) of the Excel worksheet template should be used if manual computation is contemplated.

Data ("D") in lines 1 – 3 and 5- 6 are obtained from the preliminary design layout. Lines 8, 9 and 10 contain the basic hydrologic information for the incremental additional area draining to B_2. The "Total Time of Concentration" T_c (line 11) is calculated for the entire composite watershed draining to B_2. It is the maximum of times of concentration of all upgradient ("previous") watersheds entering B_2 as well as the incremental area A_2. In this case, there is just one "previous" watershed (T_c = 12 + 0.8 = 12.8 min); do not forget to add the inlet pipe travel time, if appropriate. Watershed A_2 has T_c = 14.2 min, so T_c of the composite watershed draining to B_2 is Max{12.8, 14.2} = 14.2 min. Total area (line 12) is the calculated sum of all areas draining to B_2; cumulated weighted runoff coefficient C (line 13) is calculated for the total area in line 12. The design rain intensity (line 14) is calculated by the equations in Table 12-2.4 or look-up in Figures 12-2.1. Runoff Direct (line 15) is runoff entering node B_2 calculated by the Rational Method. Runoff Offsite (line 16) is an optional data entry item to include additional runoff entering the system that is not included in the Rational calculation; in most cases this entry is 0. The direct and offset runoffs are summed to get the total runoff Q_{tot} (line 17).

Pipe design information is entered in lines 18 (Manning's roughness n) and 19 (target flow depth fraction). Ordinarily, the nominal flow depth fraction (h^* = h/D) is entered as 1, i.e., a full flowing pipe. Since pipes come in incremental sizes, the final design size will be something larger than the exact solution and the flow depth fraction will be something less than 1. A smaller target fraction can be specified if a greater degree of conservatism is desired; the Hydrology Section should be consulted in such cases so that artifacts in the mathematical solution can be accounted for. The remaining lines in the worksheet are completed by automatic calculation in the worksheet or by a combination of calculation ("C") and look-up ("L") in manual calculations.

The exact solution for a fully flowing pipe with capacity equal to the runoff in line 17 is reported in line 20. The next available pipe size (in 150 mm increments) is calculated in the worksheet; in manual calculations the actual size must be specified. Basic geometric and hydraulic quantities are calculated in lines 22 – 26. Line 27 calculates the partial flow depth fraction. This is a complicated calculation and for manual calculation Figure 12-5.6 should be used to look up the depth fraction h^* (= h/D) for a specified flow fraction Q^* ($=Q_{tot}/Q_f$). Once h^* has been calculated or looked up, the actual partial flow depth is calculated in line 28. And for the h^* value, the corresponding dimensionless partial velocity v^* is either calculated automatically or looked up, from which the partial flow velocity is calculated ($v = v^* v_f$) in line 29. Finally, knowing the partial flow velocity, the travel time in pipe is calculated in line 30.

For simple series configurations, this process is repeated until the outlet is reached.

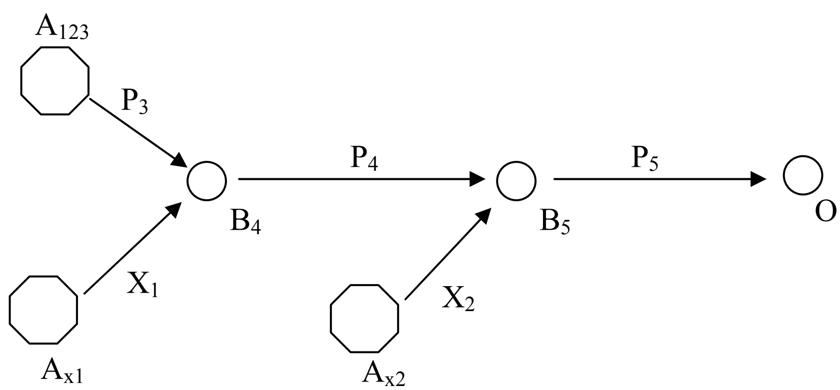
Table 12-5.8: Example of Closed System Design – Sizing Pipe P_2 by Manual Calculation

	Item	**Source**	**Variable**	**Notes**
1	Route/Street/Watershed ID	D	B_2	
2	From station	D	$x_0 = 75$ ft	From layout
3	To station	D	$x_1 = 475$ ft	From layout
4	Length	C	$x_1 - x_0 = 225$ ft	
5	Invert Elev Upper end	D	$z_0 = 107$ ft	From layout
6	Invert Elev Lower End	D	$z_1 = 103.5$ ft	From layout
7	Slope	C	$(x_1\text{-}x_0)/(z_1\text{-}z_0) = 0.016$ ft/ft	
8	Time of Conc T_c	D	14.2 min	From hydrology
9	Incremental Area	D	$A_{inc} = 8.8$ ft^2	From hydrology
10	Total T_c	C	Max{14.2, 13.1} = 14.2 min	Max{incremental area T_c OR T_c of area entering catch basin by inlet pipe)
11	Total area A_{tot}	C	$A_{tot} = A_{prev} + A_{inc}$ $= 7 + 8.8 = 15.8$ ft^2	
12	Incremental Rational C	D	C = 0.72	From hydrology
13	Cumulative Weighted C	C	{7x.4 + 8.8x.72}/15.8 = 0.58	For total area draining to CB
14	Rainfall Rate	C/L	3.7 in/hr	10-yr intensity for specified region
15	Runoff Direct	C	$Q = \mu CiA = 33.4$ ft^3/s	Rational Equation
16	Runoff offsite	D	0.0	Additional runoff source
17	Runoff total	C	$Q_{tot} = Q + Q_{off} = 33.4$ ft^3/s	Total runoff to catch basin
18	Manning roughness n	D	0.013	
19	Flow depth fraction	D	1	Usually = 1
20	Pipe Diam (in)	C	$D = (1.55\alpha/\lambda^{3/8})\{nQ/S^{1/2}\}^{3/8}$ $= 25.5$ in	Exact solution
21	Pipe Diam (design;in)	C	D = 27 in = 2.25 ft	Rounded to next size
22	Pipe Area (full)	C	$A_f = \pi D^2/4 = 3.97$ ft^2	
23	Hydraulic Radius (full)	C	$R_{h,f} = D/4 = 0.5625$ ft	
24	Pipe Full Velocity	C	$v_f = \lambda R_h^{2/3} S^{1/2}/n = 9.9$ ft/s	Manning's equation
25	Pipe Full Capacity	C	$Q_f = Av = 39.1$ ft^3/s	
26	Percent of Full Capacity	C	$Q^* = Q/Q_f = 100x33.4/39.1 = 85\%$	
27	Flow Depth Fraction	C/L	$H^* = 0.70$	Look up for Q^* value
28	Flow depth	C/L	$h = h^*D = (0.70)(27) = 18.9$ in	
29	Velocity	C/L	$V^* = 1.10 \Rightarrow v = v^* v_f = 10.9$ ft/s	Look up v^* for h^* value
30	Travel time in pipe	C	$T_t = L/60v = 225/60/10.9 = 0.34$ min	

Note: *U.S. Customary, $\lambda = 1.486$, $\mu = 1$, $\alpha = 12$; metric, $\lambda = 1$, $\mu = 0.28$, $\alpha = 1000$*

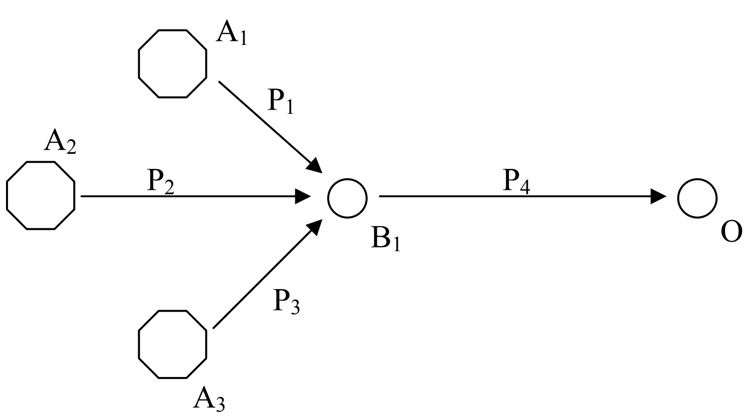
Source: D = specified data; C = calculation; L = look-up

As noted, this is an example of a simple branching network. Basins 1, 2, and 3 are in series; the system branches at B_4 and B_5. Looking upgradient from B_4, the network branches across the street to subwatershed A_{x1} and to the series of basins $B_3 – B_1$. The network can be redrawn with a single composite watershed A_{123} replacing A_1, A_2 and A_3. Pipe P_3 is already sized; cross-pipe X_1 is also sized in the usual manner. The composite watershed A_{123} is characterized by the sum of the component areas, the maximum of the component times of concentration (including pipe travel times), and the area-weighted average of the component runoff coefficients. Now pipe P_4 can also be sized in the usual manner, with two watersheds(A_{B3} and A_{x1}) draining to node B_4. Similarly, there are two watersheds draining to B_5, the composite A_{B4} (A_{B3} and A_{x1}) and A_{x2}. This treatment is illustrated in the Excel worksheet in Figure 12-5.9; manual calculations would proceed in the same manner. The compositing procedure is described in the next section for a triple branch.



Branching to Three or More Stems

A branch node with 3 or more stems might look like the following:



The single pipes $P_1 – P_3$ draining the individual watersheds are sized in the usual manner. The problem is to size the outlet pipe P_4 in the framework of the algorithm presented earlier. There are several approaches, probably the simplest being to combine the individual watersheds into a single composite. Following that, the regular algorithm can be applied. The Excel worksheet for the above schematic is shown in Figure 12-5.10. The individual inlet pipes $P_1 – P_3$ are sized in

the first three columns. In the fourth column, the outlet pipe P_4 is sized for the single composite watershed. Note that the area is sum of the individual areas, T_c is the maximum of the three individual T_c values, and the runoff coefficient C is the weighted average of the individual values. The procedure can be used for any number of pipes (and watersheds) entering a catch basin.

Figure 12-5.10: Closed System with Triple Branching

Closed System Worksheet - Preliminary Design of Simple Systems

Start data entry from bottom; enter data in blue cells only.

Units: US
Design Event: 10

1/10/2005

Pin # 9999.99

Project: Triple Branch Example

Section		No.	Parameter	Units								
Design of Closed System	Partial Flow	30	Time in Pipe Section	min	0.6		0.6		0.7		0.6	
		29	Velocity (design) =V	ft/s	5.3		8.2		5.6		7.1	
		28	Flow Depth (design)	in	17		20		21		29	
		27	Flow Depth Fraction (design)		0.80		0.81		0.78		0.73	
		26	Percent of Capcity Q_F		98		99		96		89	
	Full Flow	25	Pipe-full Capacity Q_F	ft3/s	11.2		22.62		19.59		52.22	
		24	Pipe-Full Velocity V_F	ft/s	4.7		7.2		4.9		6.3	
		23	Hydraulic Radius	ft	0.44		0.50		0.56		0.81	
		22	Pipe Area	ft2	2.41		3.14		3.98		8.30	
	Pipe Design	21	***Pipe Diam (design)***	***in***	***21***		***24***		***27***		***39***	
		20	Pipe Diam (exact)	in	21		24		27		37	
		19	Flow Depth Fraction (nom)		1		1		1		1	
		18	Manning Roughness Coeff = n		0.013		0.013		0.013		0.013	
Runoff Calculation		17	Runoff Total (design) Q_T	ft3/s	11.0		22.5		18.742		46.331	
		16	Runoff Offsite = Q_{off}	ft3/s	0.0		0.0		0.0		0.0	
		15	Runoff Direct Q = µCiA	ft3/s	11.0		22.5		18.742		46.331	
		14	Rainfall Rate I	in/hr	3.9		3.6		3.1		3.1	
		13	Cum Wt'ed C		0.40		0.70		0.60		0.58	
		12	Total Area =A_T	ac	7.0		9.00		10.0000		26.0000	
		11	Total T_c (min)	min	12.00		15.00		20.00		20.74	
		10	Incremental Rational Coeff=C		0.4		0.70		0.60		0.58	
		9	Incremental Area A_I	ac	7.0		9.0		10.0		26.0	
		8	Time of Conc T_c	min	12.0		15.0		20.0		20.7	
System	Topography	7	slope S	ft/ft	0.0050		0.0100		0.0040		0.0040	
		6	Inv Elev Lower End	ft	100.00		100.00		100.00		100.00	
		5	Inv Elev Upper End	ft	101.00		103.00		101.00		101.00	
		4	Length (m)	ft	200.00	0.00	300.00	0.00	250.00	0.00	250.00	0.00
	Location	3	To Station (lower)	ft	200		300		250		250	
		2	From Station (upper)	ft	0		0		0		0	
		1	CB/Node		A_1		A_2		A_3		B_1	

Precip Station	1	(Portland-1/Eastport-2/Rangely-3/ Presque Isle-4/Newport-5/Millinocket-6)
Event Return Period (yrs)	10	

Units

12-6 REFERENCES

Applied Microcomputer Systems, Inc., 2003. *HydroCad*, Version 7, Chocorua, NH.

Benson, M.A., 1962. Factors influencing the occurrence of floods in a humid region of diverse terrain. *Water-Supply Paper 1580-B*, U.S. Geological Survey, Lakewood, CO.

Dudley, R., G. Hodgkins, A. Mann, and J. Chisholm, 2001. Evaluation of the effects of suburban development on peak-flow hydrographs for Collyer Brook, Maine, *Water Resources Investigations Report 01-4156*, U.S Geological Survey, Augusta, ME.

Federal Highway Administration, *Hydraulic Design Series #5*, Hydraulic Design of Culverts, September 1985.

Federal Highway Administration, *Hydraulic Design Series #2*, Highway Hydrology, September 1997.

Federal Highway Administration, *Hydraulic Engineering Circular #12*, Drainage of Highway Pavement, March, 1984.

Federal Highway Administration, *Hydraulic Engineering Circular #14*, Energy Dissipators for Culverts and Channels, 2000.

Federal Highway Administration, *Hydraulic Engineering Circular #22 (2nd Ed.)*, Urban Drainage Manual, August, 2001.

Hodgkins, 1999. Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals, *Water-Resources Investigations Report 99-4008*, U.S. Geological Survey, Augusta, ME.

Izzard, C.F., 1946. Hydraulics of runoff from developed surfaces. *Proc. Highway Research Board*, 26: 129-150, Highway Research Board, Washington, D.C.

Maidment, D.R., 1992. *Handbook of Hydrology*, McGraw-Hill, NY.

Maine DEP, 1995. Stormwater Management for Maine: Best Management Practices, Augusta, Maine, November.

Maine DOT, 1/2005. Fish Passage Policy and Design Guide, Augusta, Maine.

Maine DOT, 9/2002. Maine DOT Best Management Practices Guide, Augusta, Maine.

McCuen, R.H., 1989. *Hydrologic Analysis and Design*, Prentice Hall, NY.

Natural Resources Conservation Service, 1986. Urban hydrology for small watersheds. *Technical Release 55*, Washinton, DC.

Natural Resources Conservation Service, 1986. Computer program for project formulation, *Technical Release 20*, Washinton, DC.

Sauer, V.B., W.O. Thomas, V.A. Stricker, and K.V. Wilson, 1983. Flood characteristics of urban watersheds in the United States, *Water-Supply Paper 2207*, U.S. Geological Survey, Lakewood, CO.

Viessman, W., J.W. Knapp, G.L. Lewis, and T.E. Harbaugh, 1977. *Introduction to Hydrology*, IEP (Harper & Row), New York, pp. 507-514.

Washington State DOT, 1997. *Hydraulics Manual (M23-03)*, Environmental & Engineering Service Center/Hydraulics Branch, Olympia, WA, available on-line, pp. 2-3 – 2-9.

Appendix 12-A

Hydraulics of Flow in Gutters

HYDRAULICS OF FLOW IN GUTTERS

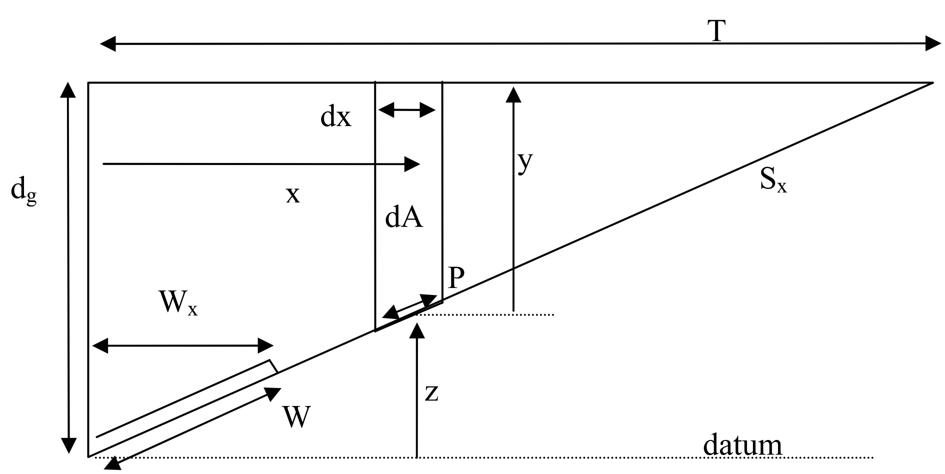
Equations for gutter flow hydraulics are developed using Manning's equation and gutter section geometry. Two section types are included in this manual, simple right-triangular and composite triangular. The equations developed here can be used to determine inlet catch basin spacing. The composite section is more efficient and has higher capacity than the simple triangular section. Often maximum spacing cannot be exploited because of other system constraints and requirements. In an urban setting, intersections usually require inlets and the intersections may be spaced closer than the hydrology and hydraulics would otherwise allow. However, on long straight runs, or on flat sections, composite gutter sections may allow for longer spacing between inlets, or simply provide the capacity unavailable with a uniform section.

Simple Right-Triangular Flow Section

The simplest gutter section is just a simple right triangle. In many applications this shape is adequate for the transmission of water closed drainage system inlets. The basic design parameters to be specified are spread T, cross-slope S_x, centerline slope S, and Manning's roughness n. Combined with hydrologic analysis, the hydraulic equation developed here can be used to calculate spacing between inlets.

Section Geometry

A simple right-triangular gutter flow section is depicted in the following schematic:



The section is defined by the following terms:

T - spread (in ft or m) of flow on the pavement
S_x - cross-section slope (ft/ft or m/m), uniform from curb to T
d_g - depth of flow at curb = S_xT
W - width of grated inlet structure

Not shown in the figure is S, the longitudinal (centerline) slope of the roadway. The other terms shown are utilized in the hydraulic analysis. Note that the reference elevation datum is the toe of curb. The depth of flow d_g at the curb is

$$d_g = S_x T$$

The final curb height should be higher than the depth of flow. The elevation of the pavement is

$$z = S_x x$$

<u>Section Hydraulics</u>

The flows of interest are the flow through the section and the flow directly intercepted by the inlet structure. Manning's equation for uniform flow is the basic tool of the hydraulic analysis:

$$v = \lambda(S^{1/2}/n)R_h^{2/3}$$

Where v = velocity
- S = longitudinal (centerline) slope of roadway
- n = Manning's roughness
- λ = unit conversion factor (1.486 in U.S. Customary; 1 in metric)
- R_h = hydraulic radius = A/P
- A = cross-sectional flow area
- P = wetted perimeter

Traditionally the flow Q (ft^3/s or m^3/s) is calculated by continuity as the simple product of sectional area and the flow velocity through the section. However, because the width of flow is much greater than the flow depth, flow is calculated here by integrating Manning's velocity equation over the sectional area (Izzard, 1946, p. 149; FHWA, 2001, p. 4-9) from the curb ($x_l = 0$) to the spread limit ($x_u = T$):

$$Q = \int v(x)dA(x) \qquad \textit{from } 0 \textit{ to } T$$
$$Q = \lambda(S^{1/2}/n) \int R_h(x)^{2/3}dA(x)$$

where x = distance from curb
- v(x) = velocity at location x from curb
- dA(x) = differential flow area at location x

From the section geometry,

$$\begin{aligned} dA(x) &= y(x) \times dx \\ y(x) &= \text{depth of flow at location } x \\ &= d_g - z = S_xT - S_xx = S_x(T-x) \\ z &= \text{elevation of pavement at location } x = S_xx \\ dx &= \text{differential flow width} \end{aligned}$$

It follows that

$$dA = S_x(T-x)dx$$

The wetted perimeter P of the incremental flow section dA is just the incremental bottom pavement dx; the vertical curb wall is ignored as it is so much smaller than the perimeter length across the section . By the Pythagorean Theorem

$$\begin{aligned} P^2 &= (dx)^2 + (dz)^2 = (dx)^2 + (S_xdx)^2 \\ P &= (1+S_x^2)^{1/2}dx \end{aligned}$$

Substituting into the hydraulic radius R_h yields

$$\begin{aligned} R_h &= dA/P \\ &= \{S_x(T-x)dx\}/\{(1+S_x^2)^{1/2}dx\} = \{S_x/(1+S_x^2)^{1/2}\}(T-x) \end{aligned}$$

.

Substituting for R_h into the integration for Q gives

$$\begin{aligned} Q &= \lambda(S^{1/2}/n)\ \{S_x/(1+S_x^2)^{1/2}\}^{2/3} \int (T-x)^{2/3}\{S_x(T-x)dx\} \\ &= \lambda(S^{1/2}/n)\ S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3} \int (T-x)^{5/3}dx \qquad \textit{from } x = 0 \text{ to } T \end{aligned}$$

The integration can be completed by substitution:

$$\begin{aligned} u &= T - x &\rightarrow\ & dx = -du \\ x_l &= 0 &\rightarrow\ & u_l = T \\ x_u &= T &\rightarrow\ & u_u = 0 \end{aligned}$$

$$\begin{aligned} Q &= -\lambda(S^{1/2}/n)\ S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3} \int u^{5/3}du \ \textit{from } u = T \text{ to } 0 \\ &= \lambda(S^{1/2}/n)\ S_x\{S_x/\{(1+S_x^2)^{1/2}\}^{2/3} \int u^{5/3}du\ \textit{from } u = 0 \text{ to } T \\ &= (3/8)\lambda(S^{1/2}/n)\ S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3}u^{8/3} \qquad \textit{from } u = 0 \text{ to } T \end{aligned}$$

$$Q = (3/8)\lambda(S^{1/2}/n)\ S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3}T^{8/3}$$

Note how the leading negative is removed by switching the lower and upper integration limits. This operation will be performed in all subsequent integrations without explicit comment.

The cross-slope S_x is a very small number (typically $S_x = 0.02$) in uniform sections, so

$$(1+S_x^2)^{1/2} \cong 1$$

and

$$Q \cong (3/8)\lambda(S^{1/2}/n)S_x^{5/3}T^{8/3}$$

In terms of flow depth at the gutter,

$$Q \cong (3/8)\{\lambda S^{1/2}/nS_x\}d_g^{8/3}$$

These last two are the forms commonly cited in the standard references (FHWA, 2001, p. 4-9).

Intercepted Flow and Interception Efficiency

The flow intercepted directly by the grated inlet is calculated by integrating the flow equation over the interval $[0 \leq x \leq W_x]$, where W_x is the inlet width projected in the x-direction:

$$W_x \quad = W/(1 + S_x^2)^{1/2}$$

As above, but with a different upper limit of integration ($x_u = W_x$ instead of T; $u_u =$ T-W_x instead of 0), the intercepted flow is

$$Q_w \quad = (3/8)\lambda(S^{1/2}/n)\, S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3}u^{8/3} \qquad \textit{from } u = (T-W_x) \text{ to } T$$

$$= (3/8)\lambda(S^{1/2}/n)\, S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3}\{T^{8/3} - (T-W_x)^{8/3}\}$$

Employing the approximation $(1+S_x^2)^{1/2} \cong 1$,

$$Q_w \quad \cong (3/8)\lambda(S^{1/2}/n)\, S_x^{5/3}\{T^{8/3} - (T-W_x)^{8/3}\}$$

The (geometric) interception efficiency E_o is the ratio of intercepted flow to total flow:

$$E_o \quad = Q_w/Q = \{T^{8/3} - (T-W_x)^{8/3}\}/T^{8/3}$$

$$= 1 - \{1 - W_x/T\}^{8/3}$$

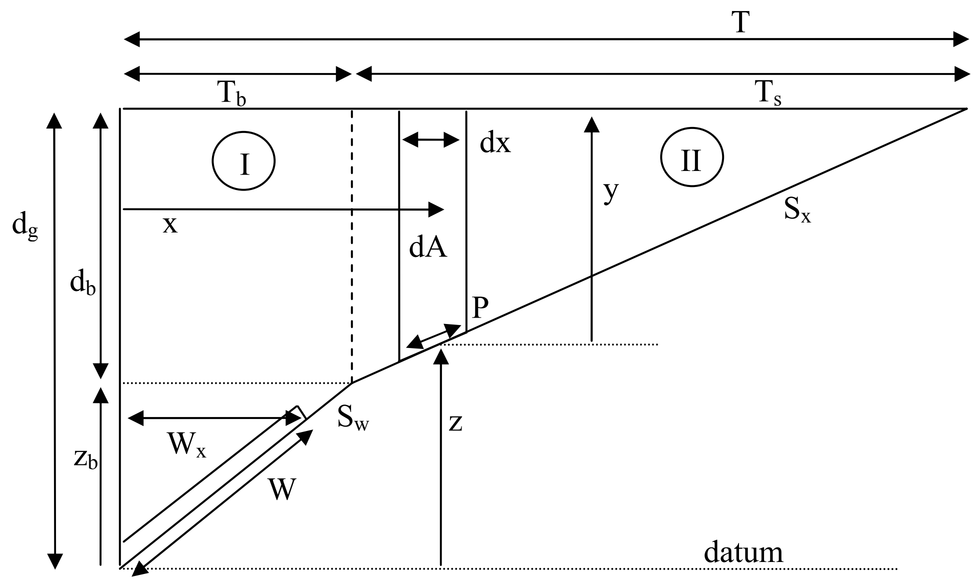
As before, W_x is closely approximated by the nominal grate width W for the small S_x values typical of gutters. Then

$$E_o \quad \cong 1 - \{1 - W/T\}^{8/3}$$

This is the form commonly cited in standard references (FHWA, 2001, p. 4-9).

<u>Composite Triangular Flow Section</u>

The hydraulic capacity of a triangular section can be significantly increased by introducing a depressed triangular section in the shoulder area and outside the travelway. The composite section consists of a steeper cross-slope S_w at the curb and the regular travelway cross-slope S_x away from the curb. This increased capacity allows for greater spacing between inlets for a specified spread T, or a reduced spread T for a specified inter-inlet spacing.



The general approach is the same as taken for a simple triangular section, i.e., integrating Manning's equation over the flow section. However, since the section is a composite of two triangular sections, the integration is done in parts corresponding to Regions I and II in the figure above. The total flow is the sum of the two component flows:

$$Q = Q_I + Q_{II}$$

The basic design parameters to be specified are spread T and distance T_b to cross-slope break, cross-slopes S_x and S_w, inlet width W ($W \le T_b$) , centerline slope S, and Manning's roughness n. Combined with hydrologic analysis, the hydraulic equation developed here can be used to calculate spacing between inlets.

<u>Region I: $0 \le x \le T_b$</u>

Fixed Elevations and Flow Depths

Pavement elevation at break in cross-slope:

$$z_b = S_w T_b$$

Depth at break in cross-slope:

$d_b = S_x(T-T_b)$

Depth at edge of inlet in shoulder:

$d_w = d_b + z_b - z_w = S_x(T-T_b) + S_wT_b - S_wW_x = S_x(T-T_b) + S_w(T_b - W_x)$

Depth at gutter curb:

$$\begin{aligned} d_g &= d_b + z_b \\ &= S_x(T-T_b) + S_wT_b \\ &= S_w\{(S_x/S_w)(T-T_b) + T_b\} \end{aligned}$$

The final design curb height should be higher than the calculated curb flow depth.

Depth of Flow y as function of position x:

$$\begin{aligned} y &= d_g - z \\ &= d_g - S_wx = S_w\{(S_x/S_w)(T-T_b) + T_b\} - S_wx \\ &= S_w\{(S_x/S_w)(T-T_b) + T_b - x\} \end{aligned}$$

Differential Flow Area as function of position x:

$$\begin{aligned} dA &= y \times dx = (d_g-S_wx)dx \\ &= \{S_w\{(S_x/S_w)T_s + T_b\} - S_wx\}dx \\ &= S_w\{(S_x/S_w)(T-T_b) + T_b - x\}dx \end{aligned}$$

Wetted Perimeter of differential flow area:

$$P = (1+S_w^2)^{1/2}dx$$

Hydraulic Radius R_h :

$$\begin{aligned} R_h &= dA/P = \{(d_g-S_wx)dx\}/\{(1+S_w^2)^{1/2}dx\} \\ &= S_w\{(S_x/S_w)(T-T_b) + T_b - x\}/(1+S_w^2)^{1/2} \\ &= \{S_w/(1+S_w^2)^{1/2}\}\{(S_x/S_w)(T-T_b) + T_b - x\} \end{aligned}$$

Manning's Equation

$$\begin{aligned} v &= \lambda(S^{1/2}/n)R_h^{2/3} \\ &= \lambda(S^{1/2}/n)[\{S_w/(1+S_w^2)^{1/2}\}\{(S_x/S_w)(T-T_b) + T_b - x\}]^{2/3} \\ &= \lambda(S^{1/2}/n)\{S_w/(1+S_w^2)^{1/2}\}^{2/3}\{(S_x/S_w)(T-T_b) + T_b - x\}^{2/3} \end{aligned}$$

Flow Equation

$$Q_I = \int v(x)dA(x) \qquad \textit{from } x = 0 \text{ to } T_b$$
$$= \lambda(S^{1/2}/n)\{S_w/(1+S_w^2)^{1/2}\}^{2/3}$$
$$\times \int\{(S_x/S_w)(T-T_b)+T_b-x\}^{2/3}\, S_w\{(S_x/S_w)(T-T_b)+T_b-x\}dx$$
$$= \lambda(S^{1/2}/n)S_w\{S_w/(1+S_w^2)^{1/2}\}^{2/3} \int\{(S_x/S_w)(T-T_b)+T_b-x\}^{5/3}\, dx$$

Integrate by substitution:

Let $u = (S_x/S_w)(T-T_b)+T_b-x \rightarrow -du = dx$

$x_l = 0 \rightarrow u_l = (S_x/S_w)(T-T_b)+T_b$

$x_u = T_b \rightarrow u_u = (S_x/S_w)(T-T_b)$

$$Q_I = \lambda(S^{1/2}/n)S_w\{S_w/(1+S_w^2)^{1/2}\}^{2/3} \int u^{5/3}\, du$$
$$\textit{from } u = (S_x/S_w)(T-T_b) \textit{ to } (S_x/S_w)(T-T_b)+T_b$$

$$Q_I = \lambda(S^{1/2}/n)S_w\{S_w/(1+S_w^2)^{1/2}\}^{2/3}(3/8)u^{8/3}$$

$$Q_I = (3/8)\lambda(S^{1/2}/n)S_w\{S_w/(1+S_w^2)^{1/2}\}^{2/3}$$
$$\times [\{(S_x/S_w)(T-T_b)+T_b\}^{8/3} - \{(S_x/S_w)(T-T_b)\}^{8/3}]$$

Employing the approximation $(1+S_w^2)^{1/2} \cong 1$ and substituting with flow depths yields:

$$Q_I \cong (3/8)\, \lambda(S^{1/2}/n)S_w^{5/3}[\{(S_x/S_w)(T-T_b)+T_b\}^{8/3} - \{(S_x/S_w)(T-T_b)\}^{8/3}]$$

$$Q_I \cong (3/8)(\lambda S^{1/2}/n)\{d_g^{8/3} - d_b^{8/3}\}/S_w$$

<u>Region II: $T_b \leq x \leq T$</u>

Elevation of Pavement z:

$$S_x = (z - z_b)/(x - T_b)$$
$$z = S_x(x-T_b) + z_b = S_x(x-T_b) + S_wT_b = (S_w - S_x)T_b + S_xx$$

Depth of Flow y:

$$y = d_g - z = S_x(T - x)$$

Area:

$$dA = y \times dx = S_x(T - x)\, dx$$

Wetted Perimeter:

$$P = (1+S_x^2)^{1/2}dx$$

Hydraulic Radius R_h :

$$R_h = dA/P = \{S_x(T - x)dx\}/\{(1+S_x^2)^{1/2}dx\}$$
$$= \{S_x/(1+S_x^2)^{1/2}\}(T-x)$$

Manning's Equation

$$v = \lambda(S^{1/2}/n)R_h^{2/3}$$
$$= \lambda(S^{1/2}/n)[\{S_x/(1+S_x^2)^{1/2}\}(T-x)]^{2/3}$$

Flow Equation

$$Q_{II} = \int v(x)dA(x) \qquad \textit{from } x = T_b \text{ to } T$$
$$= \lambda(S^{1/2}/n)\int [\{S_x/(1+S_x^2)^{1/2}\}(T-x)]^{2/3}\, S_x(T–x\}dx$$
$$= \lambda(S^{1/2}/n)S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3} \int(T–x)^{5/3}\, dx$$

Integrate by substitution:

$$\text{Let} \quad u = T – x \quad \rightarrow \quad -du = dx$$
$$x_l = T_b \quad \rightarrow \quad u_l = T – T_b$$
$$x_u = T \quad \rightarrow \quad u_u = 0$$

$$Q_{II} = \lambda(S^{1/2}/n)S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3} \int u^{5/3}\, du \qquad \textit{from } u = 0 \textit{ to } T – T_b$$
$$Q_{II} = \lambda(S^{1/2}/n)S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3}(3/8)u^{8/3}$$

$$Q_{II} = (3/8)\lambda(S^{1/2}/n)S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3}(T-T_b)^{8/3}$$

Employing the approximation $(1+S_x^2)^{1/2} \cong 1$ and substituting with flow depth:

$$Q_{II} \cong (3/8)\lambda(S^{1/2}/n)S_x^{5/3}(T-T_b)^{8/3}$$
$$Q_{II} \cong (3/8)(\lambda S^{1/2}/n)d_b^{8/3} /S_x$$

Total Gutter Flow

$$Q = Q_I + Q_{II}$$

$$Q = (3/8)\lambda(S^{1/2}/n)S_w\{S_w/(1+S_w^2)^{1/2}\}^{2/3}$$
$$\times [\{(S_x/S_w)(T-T_b)+T_b\}^{8/3} – \{(S_x/S_w)(T-T_b)\}^{8/3}]$$

$$+ (3/8)\lambda(S^{1/2}/n)S_x\{S_x/(1+S_x^2)^{1/2}\}^{2/3}(T-T_b)^{8/3}$$

This form, while complicated, is recommended for use in computer-based application. For manual calculations, the approximation in terms of flow depths is easier to use:

$$Q \cong (3/8)(\lambda S^{1/2}/n)\{d_g^{8/3} – d_b^{8/3}\}/S_w + (3/8)(\lambda S^{1/2}/n)d_b^{8/3} /S_x$$

$$Q \cong (3/8)(\lambda S^{1/2}/n)\{(d_g^{8/3} - d_b^{8/3})/S_w + d_b^{8/3}/S_x\}$$

where $d_b = S_x(T\text{-}T_b)$ and $d_g = S_wT_b + S_x(T\text{-}T_b)$.

Intercepted Flow and Interception Efficiency

The flow intercepted directly by the grated inlet is calculated by integrating the flow equation over the interval $[0 \le x \le W_x]$, where W_x is the inlet width projected in the x-direction ($W \le T_b$ always).

$$W_x = W/(1 + S_w^2)^{1/2}$$

As above for the flow in Region I, but with a different upper limit of integration ($x_u = W_x$ instead of T_b; $u_u = (S_x/S_w)(T\text{-}T_b)+T_b\text{-}W_x$ instead of $(S_x/S_w)(T\text{-}T_b)$), the intercepted flow is

$$Q_w = (3/8)\lambda(S^{1/2}/n)\, S_w\{S_w/(1+S_w^2)^{1/2}\}^{2/3}u^{8/3} \quad \textit{from } u = (S_x/S_w)(T\text{-}T_b)+T_b\text{-}W_x \textit{ to } (S_x/S_w)(T\text{-}T_b)+T_b$$

$$= (3/8)\lambda(S^{1/2}/n)\, S_w\{S_w/(1+S_w^2)^{1/2}\}^{2/3} \times [\{(S_x/S_w)(T\text{-}T_b)+T_b\}^{8/3} - \{(S_x/S_w)(T\text{-}T_b)+T_b\text{-}W_x\}^{8/3}]$$

Employing the approximation $(1+S_w^2)^{1/2} \cong 1$,

$$Q_w \cong (3/8)\lambda(S^{1/2}/n)\, S_w^{5/3}[\{(S_x/S_w)(T\text{-}T_b)+T_b\}^{8/3} - \{(S_x/S_w)(T\text{-}T_b)+T_b\text{-}W_x\}^{8/3}]$$

Substituting with flow depths gives

$$Q_w \cong (3/8)(\lambda S^{1/2}/n)\{d_g^{8/3} - d_w^{8/3}\}/S_w$$

The (geometric) interception efficiency E_o is the ratio of intercepted flow to total flow:

$$E_o = Q_w/Q = Q_w/(Q_I + Q_{II})$$

As before, W_x is closely approximated by the nominal grate width W for the small S_w values typical of gutters.

Appendix B

Tables in Metric Units

Table 12-1.2: Preferred Units for Hydrologic and Hydraulic Analysis and Design

Quantity	Symbol	Units
Flow Path Length	L	m or km
Area	A	km^2
Flow Rate	Q	m^3/s
Rainfall Intensity	I	mm/hr
Pipe Diameter	D	mm
Time of Concentration	t_c	min
Slope	S	m/m or m/km

Table 12-2.1: Methods[1] for Peak Flow Calculation for Culverts & Ditches

Watershed Area	Rural	Urban
< 1.25 km^2 (= 320 ac)	Rational and Modeling	Rational and Urban USGS[3]
1.25 – 2.5 km^2 (= 640 ac = 1 mi^2)	Rational, USGS[2,5] and Modeling[4]	Rational, Urban USGS and Modeling
> 2.5 km^2	USGS	Urban USGS

Notes:
1) At the discretion of MDOT, other methods may be used on a project-specific basis
2) USGS indicates USGS (Hodgkins, 1999) regression equations (Water-Resources Investigations Report 99-4008, USGS, Augusta, ME, 1999)
3) Urban USGS indicates regression equations with Sauer correction for urbanization as documented in Hodgkins (1999)
4) Modeling will generally be performed with TR-20 or equivalent. MDOT may approve alternative models on a project-specific basis. See further comments on use of modeling.
5) USGS is only a secondary method for small watersheds (<2.5 km^2)

Table 12.2-3: Limits for Peak Flow Regression Applicability

Minimum	Parameter	Maximum
2.5	< A (km^2) <	4,300
0.7	< W (%) <	27
----	< Benson Slope (m/km) <	50

Table 12-2.4: Coefficients for Maine Intensity-Duration-Frequency Curves

	Portland	Eastport	Rangeley	Presque Isle	Newport	Millinocket
10 yr - a	782.8	603.7	989.6	1017.2	804.1	850.7
b	0.686	0.665	0.754	0.807	0.722	0.744
c	8.133	6.466	8.208	8.357	7.158	8.172
50 yr - a	1050.1	914.6	1543.7	1399.4	1161.9	1280.4
b	0.691	0.688	0.790	0.809	0.738	0.769
c	8.956	7.744	10.019	9.779	8.803	9.512
100 yr - a	1208.9	1045.8	2096.0	1589.7	1236.8	1131.3
b	0.698	0.691	0.826	0.810	0.726	0.721
c	9.921	8.452	12.368	10.01	8.478	7.727

Note: IDF equation is $i = a/(t_d + c)^b$, i in(mm/hr), t_d in (min)

Table 12-2.7: Typical Manning's "n" and Hydraulic Radius Values (McCuen, 1989)

Land Use/Flow Regime	Manning's n	Hydraulic Radius R_h (mm)	k ($m^{2/3}$) $= R_h^{2/3}/n$	k ($ft^{2/3}$) $= 1.486R_h^{2/3}/n$
Forest				
Light underbrush	0.4	67.0	0.41	1.4
Heavy ground litter	0.2	61.0	0.77	2.5
Grass				
Bermudagrass	0.41	45.7	0.31	1.0
Dense (Lawns, Playing fields)	0.24	36.6	0.46	1.5
Short	0.15	30.5	0.65	2.1
Short grass pasture	0.025	12.2	2.12	7.0
Conventional tillage				
With residue	0.19	18.3	0.37	1.2
No residue	0.09	15.2	0.67	2.2
Agricultural				
Cultivated straight row	0.04	36.6	2.75	9.1
Contour or strip crop	0.05	18.3	1.39	4.6
Trash fallow	0.045	15.2	1.36	4.5
Rangeland	0.13	12.2	0.41	1.3
Alluvial fans	0.017	12.2	3.11	10.3
Grassed waterways	0.095	305.0	4.77	15.7
Small upland gullies	0.04	152.5	7.13	23.5
Pavement (smooth; sheet flow)	0.011	18.3	6.30	20.8
Pavement (rubble; sheet flow)	0.025	61.0	6.19	20.4
Paved gutter	0.011	61.0	14.07	46.3

Note: $k(m^{2/3}) = k(ft^{2/3})/3.28$

Table 12-4.1

CIRCULAR CULVERT PIPES – WALL THICKNESSES

	Nominal Pipe Wall Thickness in (mm)							
	Corrugated Metal				Plastic	Reinforced Concrete		
	Option I		Option I/III		Option III	Option I/III		
Diameter (mm)	M 218	M 274	M-246 & Fiber Bonded	M 197	M 278	M 170 Class III Wall A	M 170 Class III Wall B	M 170 Class III Wall C
300	2.0	1.63	1.63	1.91	9.09	44.5	50.8	
375	2.0	1.63	1.63	1.91	11.1	47.6	57.2	
450	2.77	2.01	2.01	1.91		50.8	63.5	
525	2.77	2.01	2.01	1.91		57.2	69.9	
600	2.77	2.01	2.01	2.67		63.5	76.2	95.3
675	2.77	2.01	2.01	2.67		66.7	82.3	101.6
750	2.77	2.01	2.01	2.67		69.9	88.9	108
825	2.77	2.01	2.01			73.0	95.3	114.3
900	2.77	2.01	2.01	1.91		76.2	101.6	120.7
900[1]			2.01					
1050	3.51	2.77	2.77	2.67		88.9	114.3	133.4
1050[1]			2.01					
1200	3.51	2.77	3.51	2.67		101.6	127	146.1
1200[1]			2.01					
1350	4.27	3.51	3.51	2.67		114.3	139.7	158.8
1350[1]			2.01					
1500	4.27	3.51	3.51	2.67		127	152.4	171.5
1500[1]			2.01	3.43				
1650[1]			2.01	3.43		139.7	165.1	184
1800[1]			2.01	4.17		152.4	177.8	196.9
1950[1]			2.01	4.17			190.5	209.6
2100[1]			2.77	4.17			203	222.3

Metal Pipe values are for 67.8 mm x 12.7 mm corrugations unless diameter is followed by (1), which requires 76.2 mm x 25.4 mm corrugations for aluminum pipes and 76.2 mm x 25.4 mm or 127 mm x 25.4 mm corrugations for steel pipes; corrugations in (mm).

Option I pipes shall only be used for entrances. Fill heights over 4.5 m may require larger metal gages.

M 170 = Reinforced Concrete Pipe M 218 = Zinc-coated (galvanized) corrugated steel pipe
M 278 = Polyvinyl Chloride Pipe M 274 = Aluminum-coated (Type 2) corrugated steel pipe
M 197 = Corrugated Aluminum Alloy Pipe M 246 = Polymer precoated galvanized corrugated steel pipe
Fiber Bonded = MDPT Spec. 707.04

Table 12-4.2
PIPE ARCH CULVERTS – WALL THICKNESSES

Nominal Wall Thickness in (mm)		
	Corrugated Metal Pipe Arch Option III	
Nominal Size in (mm) Span x Rise	**M 246 & Fiber Bonded**	**M 197**
533 x 381	2.00	1.91
610 x 457	2.00	1.91
711 x 508	2.00	2.67
889 x 610	2.77	2.67
1016 x 787 [1]	2.00	1.91
1067 x 737 [2]	2.77	1.91
1168 x 914 [1]	2.00	2.67
1245 x 838 [2]	3.51	2.67
1346 x 1041 [1]	2.00	2.67
1448 x 965 [2]	3.51	2.67
1524 x 1168 [1]	2.77	3.43
1626 x 1092 [2]	4.27	3.43
1676 x 1295 [1]	2.77	3.43
1854 x 1397 [1]	2.77	4.17
2057 x 1499 [1]	2.77	4.17

Coated Steel Pipe Equivalents (mm)
18 gage = 1.32
16 gage = 1.63
14 gage = 2.00
12 gage = 2.77
10 gage = 3.51
8 gage = 4.27

Aluminum Pipe Equivalents (mm)
18 gage = 1.22
16 gage = 1.52
14 gage = 1.91
12 gage = 2.67
10 gage = 3.43
8 gage = 4.17

Metal pipe values are for 67.8 mm x 12.7 mm corrugations unless size is followed by a (1), which denotes 76.2 mm x 25.4 mm corrugations.

M 246 = Polymer pre-coated galvanized corrugated steel pipe
M 197 = Corrugated Aluminum Alloy Pipe
Fiber Bonded = MDOT Spec. 707.04

Minimum Cover is 1 m
(2) = Either size is acceptable

Table 12-4.3
COUPLING BAND WIDTH REQUIREMENTS

Nominal Corrugation (mm)	Nominal Pipe Inside Diam (mm)	Coupling Band Width			
		Annular Corrugated Bands		Helically Corrugated Bands	
		M 196	M 36	M 196	M 36
38 x 6.4	150	267	267	178	178
68 x 12.8	300 - 2100	267	267		
76.2 x 25.4	750 - 2100	305	305		
127 x 25.4	900 - 2100		508		

Helically corrugated pipe 300 mm diameter and larger shall have the ends rerolled to provide at least two annular corrugations.

Pipe with spiral corrugations shall have continuous helical lock seams.

M 196 = Corrugated Aluminum Alloy Pipe
M 36 = Corrugated Steel Pipe

Table 12-4.4
TYPES B & C UNDERDRAIN PIPE

Metal Pipe				Plastic Pipe Stiffness @ 5% Deflection			
Nominal Wall Thickness (mm)				PVC Pipe		Polyethylene Pipe	
Diameter (mm)	M 218	M 274 M 246	M 197	M 278	ASTM F 949	M 294 SP Dual-Wall Unanchored	M 252 SP Dual-Wall Unanchored
Type “B” 150	1.63	1.32	1.22	46	50		60
Type “C” 300	2.00	1.63	1.91	46		50	
375	2.00	1.63	1.91	46		42	
450	2.00	1.63	1.91			40	
525	2.00	1.63	1.91				
600	2.00	1.63	1.91			40	
750	2.77	2.00	2.67				
900	2.77	2.00	2.67				

\

TABLE 12-4.5
MAXIMUM ALLOWABLE HEIGHT OF FILL IN METERS

Diameter (mm)	Class III	Class IV	Class V
300	3.48	4.99	6.41
375	3.57	5.27	6.58
450	3.64	5.37	6.70
600	3.73	5.50	6.86
750	3.80	5.59	6.97
900	3.85	5.66	7.05
1050	3.89	5.71	7.11
1200	3.92	5.75	7.16
1350	3.95	5.79	7.20
1500	3.98	5.82	7.23
1650	4.00	5.85	7.27
1800	4.03	5.88	7.30

Note: These fill heights have been derived assuming a soil mass of 2000 kg/m^3 (2 g/cm^3 = 125 lbs/ft^3) and a safety factor of 1.5 times the ultimate pipe strength.

TABLE 12-4.6
MAXIMUM ALLOWABLE HEIGHT OF FILL IN METERS
(Zero Projecting Conduit)

Diameter (mm)	Class III	Class IV	Class V
300	4.77	7.06	8.82
375	4.90	7.25	9.05
450	4.99	7.38	9.21
600	5.11	7.55	9.43
750	5.19	7.66	9.57
900	5.25	7.74	9.66
1050	5.30	7.81	9.74
1200	5.34	7.86	9.80
1350	5.37	7.90	9.84
1500	5.39	7.93	9.89
1650	5.42	7.96	9.92
1800	5.44	7.99	9.95

Note: These fill heights have been derived assuming a soil mass of 2000 kg/m^3 (2 g/cm^3 = 125 lbs/ft^3) and a safety factor of 1.5 times the ultimate pipe strength.

TABLE 12-4.7
MAXIMUM HEIGHTS OF FILL (Corrugated Metal Pipe)

Diameter	Std Thk (mm) /	Non-Std Thk (mm)/	Non-Std Thk (mm)/	Non-Std Thk

(mm)	Height of Fill (m)	Height of Fill (m)	Height of Fill (m)	(mm)/ Height of Fill (m)
300 & 375	1.63 / 0.5 – 13.7			
450	1.63 / 0.5 – 10.7	2.00 / 10.7 – 16.8		
525	1.63 / 0.5 – 10.7	2.00 / 10.7 – 15.2	2.77 / 15.2 – 16.8	
600	1.63 / 0.5 – 6.1	2.00 / 6.1 – 12.2	2.77 / 12.2 – 15.2	3.51 / 15.2 – 18.3
750	2.00 / 0.5 – 7.6	2.77 / 7.6 – 12.2	3.51 / 7.6 – 13.7	4.27 / 16.8 – 18.3
900	2.00 / 0.5 – 4.6	2.77 / 4.6 – 7.6	3.51 / 7.6 – 13.7	4.27 / 13.7 – 18.3
1050	2.77 / 0.5 – 6.1	3.51 / 6.1 – 10.7	4.27 / 10.7 – 18.3	
1200	2.77 / 0.5 – 7.6	3.51 / 6.1 – 15.2	4.27 / 15.2 – 18.3	
1350	2.77 / 0.5 – 6.1	3.51 / 6.1 – 12.2	4.27 / 12.2 – 15.2	
1500	3.51 / 0.5 – 7.6	4.27 / 7.6 – 13.7		
1650	3.51 / 0.5 – 6.1	4.27 / 6.1 – 12.2		
1800	4.27 / 0.5 – 9.1			

Notes:

1) This table applies to metal pipe with smoothlined corrugations and 67.8 mm x 12.7 mm corrugations.
2) Shop strut for pipe diameters of 1200 mm and larger.

TABLE 12-4.8
CORRUGATED STEEL PIPE ARCHES
(Corrugations of 67.8 mm x 12.7 mm)

Equivalent Pipe Diam (mm)	Span (mm)	Rise (mm)	Height of Fill Above Top of Arch (m)			
			0.5 – 1	1.2 – 1.5	1.8 – 3	3.4 – 4.6
			Wall Thickness (mm)			
375	450	279	1.52	1.52	1.52	1.52
450	559	330	1.52	1.52	1.52	1.52
600	737	450	1.91	1.91	1.91	1.91
750	900	559	1.91	1.91	1.91	1.91
900	1092	686	2.67	2.67	2.67	2.67
1050	1270	787	2.67	2.67	2.67	2.67
1200	1473	900	3.43	2.67	2.67	3.43
1350	1651	1016	3.43	3.43	3.43	4.17
1500	1823	1118	4.17	4.17	4.17	

Note: minimum cover is 450 mm (18 in).

Table 12-3.9

STRUCTURAL PLATE STEEL CIRCULAR PIPE

(corrugations of 150 mm x 50 mm)

Dia (mm)	Area (m^2)	Min Filll (m)	Height of Fill Above Top of Steel Pipe (meters): Min - 1.5	1.5 - 3	3 - 4.5	4.5 - 6	6 - 7.5	7.5 - 9	9 - 10.5	1.05 - 12	12 - 13.5	13.5 - 15	15 - 16.5	16.5 - 18	18 - 21	21 - 24	24 - 27	27 - 30	30 - 33	33 - 36
			For Steel Thicknesses (mm)																	
1500	1.77	0.45	2.77	2.77	2.77	2.77	2.77	2.77	3.51	3.51	3.51	3.51	4.27	4.27	4.78	5.54	5.54	6.32	7.11	•
1650	2.14	0.45	2.77	2.77	2.77	2.77	2.77	3.51	3.51	3.51	3.51	3.51	4.27	4.78	4.78	5.54	6.32	7.11	•	•
1800	2.54	0.45	2.77	2.77	2.77	2.77	2.77	3.51	3.51	3.51	4.27	4.27	4.78	4.78	5.54	6.32	6.32	7.11	•	◆
1950	2.99	0.45	2.77	2.77	2.77	2.77	2.77	3.51	3.51	4.27	4.27	4.78	4.78	5.54	6.32	6.32	7.11	•	•	◆
2100	3.46	0.45	2.77	2.77	2.77	2.77	3.51	3.51	3.51	4.27	4.27	4.78	4.78	5.54	6.32	7.11	•	•	◆	
2250	3.98	0.45	3.51	3.51	3.51	3.51	4.27	3.51	4.27	4.27	4.27	4.78	5.54	5.54	6.32	7.11	•	◆	◆	
2400	4.52	0.45	3.51	3.51	3.51	3.51	4.27	4.27	4.27	4.27	4.78	5.54	5.54	6.32	7.11	•	•	◆		
2550	5.11	0.6	3.51	3.51	3.51	3.51	4.27	4.27	4.27	4.78	4.78	5.54	6.32	6.32	7.11	•	◆	◆		
2700	5.73	0.6	3.51	3.51	3.51	3.51	4.27	4.27	4.27	4.78	5.54	5.54	6.32	7.11	•	•	◆			
2850	6.38	0.6	3.51	3.51	3.51	3.51	4.78	4.27	4.78	4.78	5.54	5.54	6.32	7.11	•	◆	◆			
3000	7.07	0.6	3.51	3.51	3.51	3.51	4.78	4.27	4.78	5.54	5.54	6.32	7.11	•	•	◆				
3150	7.79	0.6	3.51	3.51	3.51	3.51	4.78	4.27	4.78	5.54	5.54	6.32	7.11	•	•	◆				
3300	8.55	0.6	4.27	3.51	3.51	3.51	4.78	4.78	5.54	5.54	6.32	7.11	•	•	◆	◆				
3450	9.35	0.6	4.27	3.51	3.51	4.27	4.78	4.78	5.54	5.54	6.32	7.11	•	•	◆					
3600	10.17	0.6	4.27	4.27	4.27	4.27	4.78	4.78	5.54	6.32	6.32	7.11	•	•	◆					
3750	11.04	0.6	4.27	4.27	4.27	4.27	4.78	4.78	5.54	6.32	7.11	•	•	◆						
3900	11.95	0.6	4.27	4.27	4.27	4.27	4.78	5.54	6.32	6.32	7.11	•	•	◆						
4050	12.88	0.6	4.78	4.27	4.27	4.27	4.78	5.54	6.32	6.32	7.11	•	◆	◆						
4200	13.85	0.6	4.78	4.27	4.27	4.78	4.78	5.54	6.32	7.11	•	•	◆	◆						
4350	14.86	0.6	4.78	4.78	4.78	4.78	5.54	5.54	6.32	7.11	•	◆	◆							
4500	15.90	0.6	4.78	4.78	4.78	5.54	5.54	6.32	6.32	7.11	•	◆	◆							

• 7.11 mm thick: 6 bolts per 0.30 m long seam

◆ 7.11 mm thick: 8 bolts per 0.30 m long seam

All other thicknesses: 4 bolts Per 0.30 m long seam

Notes:

1. As design requires for added resistance to abrasion and/or corrosion, use next heavier thickness (maximum 7.11 mm) for bottom plate(s).
2. All structural plate pipes must be 5% elliptical.
3. 4- and 6-plate pipes should have 1 bottom plate; 8- and 10-plate pipes should have 3 bottom plates.

Table 12-4.10
STEEL STRUCTURAL PLATE PIPE ARCHES

(Corrugations of 150 mm x 50 mm)

Span	Rise	Area	Corner Plate Radius	Min Fill	Height of Fill Above Top of Pipe Arches (m)											
					0.6	0.9	1.2	1.5–2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.3	4.6
(m)	(m)	(m^2)	(mm)	(m)	For Steel Thickness (mm)											
1.85	1.40	2.04	457	0.60	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
1.93	1.45	2.23	457	0.60	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
2.06	1.50	2.42	457	0.60	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
2.13	1.55	2.60	457	0.60	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
2.21	1.60	2.88	457	0.60	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51	3.51
2.34	1.65	3.07	457	0.60	3.51	3.51	3.51	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51	3.51
2.41	1.70	3.25	457	0.60	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
2.49	1.75	3.53	457	0.75		3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
2.62	1.80	3.72	457	0.75		3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
2.69	1.85	4.00	457	0.75		3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
2.84	1.91	4.28	457	0.75		3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
2.90	1.96	4.55	457	0.75		3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
2.97	2.01	4.83	457	0.75		3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	4.27
3.13	2.06	5.11	457	0.75		3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	4.27	4.27
3.25	2.11	5.39	457	0.75		3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	4.27	4.27	4.27
3.33	2.16	5.67	457	0.75		4.27	4.27	3.51	3.51	3.51	3.51	3.51	3.51	4.27	4.27	4.77
3.48	2.21	5.95	457	0.75		4.27	4.27	4.27	3.51	3.51	3.51	3.51	4.27	4.27	4.27	4.77
3.53	2.26	6.23	457	0.75		4.27	4.27	4.27	3.51	3.51	3.51	3.51	4.27	4.27	4.77	4.77
3.63	2.31	6.60	457	0.75		4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.77	4.77
3.76	2.36	6.88	457	0.75		4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.77	4.77
3.81	2.41	7.25	457	0.75		4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.77	4.77
3.86	2.46	7.53	457	0.75		4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.77	4.77	
3.91	2.54	7.90	457	0.75		4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.77	4.77	
4.09	2.57	8.27	457	0.75		4.77	4.27	4.27	4.27	4.27	4.27	4.77	4.77	4.77	4.77	
4.24	2.62	8.64	457	0.75		4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77		
4.29	2.67	9.01	457	0.75		4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77		
4.34	2.72	9.39	457	0.75		4.77	4.77	4.77	4.77	4.77	4.77	4.77	5.54			
4.52	2.77	9.76	457	0.75		4.77	4.77	4.77	4.77	4.77	5.54	5.54	5.54			
4.67	2.82	10.13	457	0.75		5.54	4.77	4.77	4.77	4.77	5.54	5.54	5.54			USE
4.73	2.87	10.50	457	0.75		5.54	5.54	4.77	4.77	4.77	5.54	5.54				
4.78	2.92	10.97	457	0.75		5.54	5.54	4.77	4.77	4.77	5.54	5.54				787 mm RADIUS
4.83	3.00	11.34	457	0.75		5.54	5.54	4.77	4.77	4.77	5.54	5.54				
5.01	3.02	11.71	457	0.75		5.54	5.54	5.54	5.54	5.54	5.54					STRUCTURES
5.06	3.07	12.17	457	0.75		5.54	5.54	5.54	5.54	5.54	5.54					
4.04	2.84	9.12	787	0.75		4.77	4.27	4.27	4.27	4.27	4.27	4.77	4.77	4.77	4.77	4.77
4.12	2.90	9.48	787	0.75		4.77	4.27	4.27	4.27	4.27	4.27	4.77	4.77	4.77	4.77	4.77
4.27	2.95	9.85	787	0.75		4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77
4.32	3.00	10.22	787	0.75		4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77
4.40	3.05	10.69	787	0.75		4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	5.54	5.54
4.55	3.10	11.06	787	0.75		4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	5.54	5.54
4.67	3.15	11.52	787	0.75		5.54	4.77	4.77	4.77	4.77	4.77	4.77	4.77	5.54	5.54	5.54
4.75	3.20	11.99	787	0.75		5.54	5.54	4.77	4.77	4.77	4.77	4.77	4.77	5.54	5.54	5.54
4.83	3.25	12.36	787	0.75		5.54	5.54	4.77	4.77	4.77	4.77	4.77	5.54	5.54	5.54	5.54
4.95	3.30	12.83	787	0.75		5.54	5.54	5.54	4.77	4.77	4.77	4.77	5.54	5.54	5.54	5.54
5.03	3.35	13.29	787	0.75		5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	
5.18	3.40	13.75	787	1.07			5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	
5.23	3.45	14.22	787	1.07			5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	
5.31	3.51	14.68	787	1.07			5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54		
5.46	3.56	15.15	787	1.07			5.54	5.54	5.54	5.54	5.54	5.54	6.32	6.32		
5.51	3.61	15.61	787	1.07			5.54	5.54	5.54	5.54	5.54	6.32	6.32	6.32		
5.67	3.66	16.17	787	1.07			5.54	5.54	5.54	5.54	5.54	6.32	6.32	6.32		
5.72	3.71	16.64	787	1.07			5.54	5.54	5.54	5.54	6.32	6.32	6.32			
5.89	3.76	17.19	787	1.07			5.54	5.54	5.54	5.54	6.32	6.32	6.32			
5.95	3.81	17.66	787	1.07			5.54	6.32	6.32	6.32	6.32	6.32	6.32			
6.00	3.86	18.22	787	1.07			5.54	6.32	6.32	6.32	6.32	6.32	6.32			
6.07	3.91	18.77	787	1.07			5.54	6.32	6.32	6.32	6.32	6.32	6.32			
6.22	3.96	19.33	787	1.07			6.32	6.32	6.32	6.32	6.32	6.32				
6.28	4.01	19.89	787	1.07			6.32	6.32	6.32	6.32	6.32	6.32				

Note: for abrasion/corrosion resistance, use next heavier thickness (max 7.11 mm) for bottom and corner plates.

Table 12-4.11

STEEL STRUCTURAL PLATE ARCHES

(Corrugations of 150 mm x 50 mm)

Span (m)	Min Cover (m)	Height of Fill Above Top of Steel Structural Plate Arch (m)								
		0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
		For Steel Thickness (mm)								
1.2 - 3	0.6						2.77	2.77	2.77	2.77
3.3	0.6	3.51	3.51	2.77	2.77		2.77	2.77	2.77	2.77
3.6	0.6	3.51	3.51	2.77	2.77		2.77	2.77	3.51	3.51
3.9	0.6	4.27	3.51	2.77	2.77		2.77	3.51	3.51	4.27
4.2	0.6	4.27	4.27	3.51	3.51		3.51	4.27	4.27	4.27
4.5	0.6	4.78	4.27	3.51	3.51		3.51	4.27	4.27	4.78
4.8	0.6	5.54	4.78	4.27	4.27		4.27	4.78	4.78	5.54
5.1	0.6	5.54	5.54	4.78	4.27	4.27	4.27	4.78	5.54	6.32
5.4	0.6	6.32	5.54	4.78	4.78	4.27	4.78	5.54	6.32	6.32
5.7	0.6	7.1 *	6.32	5.54	5.54	4.78	5.54	6.32	6.32	7.1
6.0	0.6	7.1 *	7.1 *	6.32	5.54	5.54	5.54	6.32	7.1	
6.3	0.6		7.1 *	6.32	6.32	5.54	6.32	7.1		
6.6	0.6			7.1	6.32	6.32	6.32	7.1		
6.9	0.6				7.1	6.32	7.1			
7.2	0.6					7.1	7.1			
7.5	0.6					7.1				

Note: * Not to be used when rise to span ratio is 0.3 or less.

Table 12-4.12
ALUMINUM ALLOY CORRUGATED CULVERT

Culvert Diameter (mm)	Type of Shape	Minimum Recommended Cover (mm) [a]	Maximum Height of Fill (m) for Pipe Thicknesses (mm)				
			1.5	1.9	2.7	3.4	4.2
300	Full Circle	200	10.7	12.2	15.2		
375	Full Circle	200	9.8	10.7	12.2		
450	Full Circle	200	7.9	9.1	10.7		
525	Full Circle	225	6.4	7.6	9.1		
600	Full Circle	225	4.0	6.4	9.1		
750	Full Circle	225		5.8	7.6	9.1	
	5% Vertically Elongated	225		7.3	9.1	10.7	
900	Full Circle	250		3.0	5.5	7.6	9.1
	5% Vertically Elongated	250			6.4	9.1	10.7
1050	Full Circle	305			4.9	6.1	7.6
	5% Vertically Elongated	305			6.1	7.6	9.1
	5% Field Strutted (b)	305			9.2	10.7	12.2
1200	Full Circle	380			4.6	6.1	7.6
	5% Vertically Elongated	380			9.1	7.6	9.1
	5% Field Strutted (b)	380			4.6	10.7	12.2
1350	Full Circle	380			5.5	6.1	7.6
	5% Vertically Elongated	380			7.6	6.7	9.1
	5% Field Strutted (b)	380				9.1	10.7
1500	Full Circle	460				4.3	5.5
	5% Vertically Elongated	460				5.1	7.6
	5% Field Strutted (b)	460				7.6	9.1
1650	Full Circle	535				4.0	5.1
	5% Vertically Elongated	535				4.6	6.1
	5% Field Strutted (b)	535				7.6	9.2
1800	Full Circle	610				3.7	4.6
	5% Field Strutted (b)	610				6.1	7.6
1950	5% Field Strutted (b)	610				4.9	6.1
2100	5% Field Strutted (b)	610					4.6
2400	5% Field Strutted (b)	610					3.0

a: For the special case of heavy construction wheeled vehicles, use 0.6 m (2 ft) cover on 900 mm (36 in) pipe and 2/3 of the diameter at greater than 900 mm diameter.
b: Field strutting is defined as shaping pipe elliptically by wire or timber strutting or careful, thorough compaction of backfill around pipe during installation.

The following apply: Loading: AASHTO – H2O Highway Shape: 67.8 mm x 12.7 mm (2-2/3 in x ½ in)
Table values are for 85% or greater compaction.

Table 12-4.13
CORRUGATED ALUMINUM PIPE ARCHES
(Corrugations of 67.8 mm x 12.7 mm)

Arch Span and Rise (mm) Helical or Annular	Minimum and Maximum Height of Cover (m) For Various Metal Thicknesses (mm)				
	1.52	1.91	2.67	3.43	4.19
432 x 330	0.3 – 4.6				
533 x 381	0.3 – 4.6				
610 x 457	0.3 – 4.3	0.3 – 4.9			
711 x 508		0.3 – 4.3			
889 x 610		0.3 – 4.0			
1067 x 737			0.4 – 4.0	0.4 – 4.9	
1245 x 838			0.4 – 3.7	0.4 – 4.9	
1448 x 965			0.4 – 2.7	.04 – 3.7	
1626 x 1092				0.45 – 3.4	0.45 – 4.3
1803 x 1194				0.6 – 2.7	0.6 – 3.4
1956 x 1321				0.9 – 2.7	0.6 – 3
2108 x 1448					0.6 – 3

Table 12-4.16
CROSS-SECTIONAL END AREAS

Round Pipe			Pipe Arch	
Normal Diameter	End Area (m^2)	Thickness (mm)	End Area (m^2)	Formed Diameter (mm)
300	0.071	1.52	0.067	356 x 254
375	0.110	1.52	0.102	432 x 330
450	0.159	1.52	0.139	533 x 381
525	0.216	1.52	0.204	610 x 457
600	0.283	1.91	0.260	711 x 508
750	0.442	1.91	0.409	889 x 610
900	0.636	2.67	0.595	1067 x 737
1050	0.866	2.67	0.809	1247 x 838
1200	1.131	2.67	1.059	1448 x 965
1350	1.431	2.67	1.329	1626 x 1092
1500	1.767	3.43	1.636	1803 x 1194
1650	2.138	3.43	1.988	1956 x 1321
1800	2.545	4.17	2.365	2108 x 1448

Note: circular pipe $A = \pi D^2/4$ (D in meters)
pipe arch $A = 0.752(w \times h)^{1.023}$ (approximate; w & h in meters)

TABLE 12-4.17
MULTIPLE-PIPE EQUIVALENCES

Diameter of Larger Pipe (mm)	Diameter of Smaller Pipe (mm)									
	300	**375**	**450**	**525**	**600**	**750**	**900**	**1050**	**1200**	**1350**
300	1									
375	1.7	1								
450	2.5	1.5	1							
525	3.6	2.2	1.4	1						
600	5	3	2	1.4	1					
750	8	5	3	2.3	1.7	1				
900	12	8	5	3.5	2.5	1.5	1			
1050	18	11	7	5	3.6	2.2	1.4	1		
1200	24	15	10	7	5	3	1.9	1.4	1	
1350	32	19	13	9	6.5	4	2.6	1.8	1.3	1
1500	41	25	16	11	8	5	3.3	2.3	1.7	1.3
1650	51	29	20	14	10	6	4	2.8	2	1.6
1800	63	37	25	17	12	7.5	5	3.5	2.5	1.9
2100	90	53	35	25	18	11	7	5	3.6	2.8

Example: One 600 mm diameter culvert is equivalent to five 300 mm culverts or two 450 mm culverts in hydraulic capacity.

Table 12-5.4
Circular Pipe Geometric and Conveyance Functions

Diameter D (mm)	Area A (m^2)	Perimeter P (m)	Hydraulic Radius R_h (m)	Conveyance C (m^3/s)	
				N = 0.012	n = 0.021
150	0.018	0.471	0.038	0.165	0.094
300	0.071	0.942	0.075	1.047	0.598
450	0.159	1.414	0.113	3.086	1.764
600	0.283	1.885	0.150	6.648	3.799
750	0.442	2.356	0.188	12.054	6.888
900	0.636	2.827	0.225	19.602	11.201
1050	0.866	3.299	0.263	29.570	16.897
1200	1.131	3.770	0.300	42.219	24.125
1350	1.431	4.241	0.338	57.801	33.029
1500	1.767	4.712	0.375	76.554	43.745
1650	2.138	5.184	0.413	98.711	56.406
1800	2.545	5.655	0.450	124.493	71.139
1950	2.986	6.126	0.488	154.119	88.068
2100	3.464	6.597	0.525	187.799	107.314
2250	3.976	7.069	0.563	225.738	128.993
2400	4.524	7.540	0.600	268.138	153.222
2550	5.107	8.011	0.638	315.194	180.111
2700	5.726	8.482	0.675	367.098	209.770
2850	6.379	8.954	0.713	424.039	242.308
3000	7.069	9.425	0.750	486.202	277.830

Notes: for Manning's equation in fully flowing circular pipe (units of meters & sec):

$v = R_h^{2/3} S^{1/2}/n$

$A = \pi D^2/4$

$P = \pi D$

$R_h = D/4$

$C = (\pi/4^{5/3})D^{8/3}/n = (0.312/n)\, D^{8/3}$

$Q = CS^{1/2}$

Table 3a
OPEN AREA IN EMBEDDED ELLIPTICAL PIPE (metric)

	Span (m)	Rise (m)	Open Area (m^2) Depth of Embedding (mm)			
			0 mm	150 mm	225 mm	300 mm
Corner Radius = 457 mm	1.855	1.397	2.048	1.854	1.733	1.602
	1.931	1.448	2.231	2.061	1.936	1.800
	2.058	1.499	2.433	2.275	2.143	2.002
	2.134	1.550	2.630	2.450	2.313	2.165
	2.210	1.601	2.838	2.638	2.493	2.338
	2.337	1.651	3.062	2.876	2.727	2.565
	2.414	1.702	3.275	3.068	2.911	2.743
	2.490	1.753	3.504	3.272	3.105	2.929
	2.617	1.804	3.743	3.533	3.371	3.185
	2.693	1.855	3.985	3.750	3.573	3.383
	2.846	1.905	4.255	4.041	3.866	3.672
	2.896	1.956	4.503	4.278	4.080	3.878
	2.973	2.007	4.767	4.501	4.303	4.092
	3.125	2.058	5.049	4.817	4.623	4.409
	3.252	2.109	5.343	5.123	4.923	4.740
	3.328	2.160	5.634	5.395	5.196	4.972
	3.481	2.210	5.950	5.727	5.541	5.321
	3.532	2.261	6.235	5.994	5.785	5.561
	3.608	2.312	6.544	6.283	6.064	5.820
	3.760	2.363	6.887	6.643	6.441	6.203
	3.811	2.414	7.194	6.932	6.706	6.461
	3.862	2.464	7.522	7.236	7.026	6.729
	3.913	2.541	7.945	7.628	7.374	7.100
	4.090	2.566	8.221	7.937	7.700	7.426
	4.243	2.617	8.600	8.335	8.115	7.854
	4.294	2.668	8.946	8.662	8.417	8.147
	4.345	2.718	9.302	8.994	7.823	8.444
	4.522	2.769	9.720	9.434	9.197	8.943
	4.675	2.820	10.122	9.855	9.631	9.367

	Span (m)	Rise (m)	Open Depth of En	
			0 mm	150 mn
	4.726	2.871	10.497	10.212
	4.776	2.922	10.884	10.579
	4.827	2.998	11.399	11.071
	5.005	3.023	11.729	11.425
	5.056	3.074	12.135	11.809
Corner Radius = 787 mm	4.040	2.846	9.080	8.833
	4.116	2.896	9.461	9.197
	4.268	2.947	9.880	9.629
	4.319	2.998	10.247	9.981
	4.395	3.049	10.646	10.360
	4.548	3.100	11.087	10.819
	4.675	3.150	11.511	11.254
	4.751	3.201	11.934	11.663
	4.827	3.252	12.370	12.073
	4.954	3.303	12.809	12.534
	5.030	3.354	13.255	12.966
	5.183	3.404	13.739	13.447
	5.234	3.455	14.017	13.724
	5.310	3.506	14.645	14.337
	5.462	3.557	15.153	14.859
	5.513	3.608	15.608	15.300
	5.666	3.659	16.131	15.835
	5.716	3.709	16.605	16.294
	5.869	3.760	17.147	16.847
	5.945	3.811	17.662	17.347
	5.996	3.862	18.160	17.830
	6.072	3.913	18.693	18.348
	6.225	3.963	19.257	18.928
	6.275	4.014	19.772	19.427

Appendix C

Figures in Metric Units

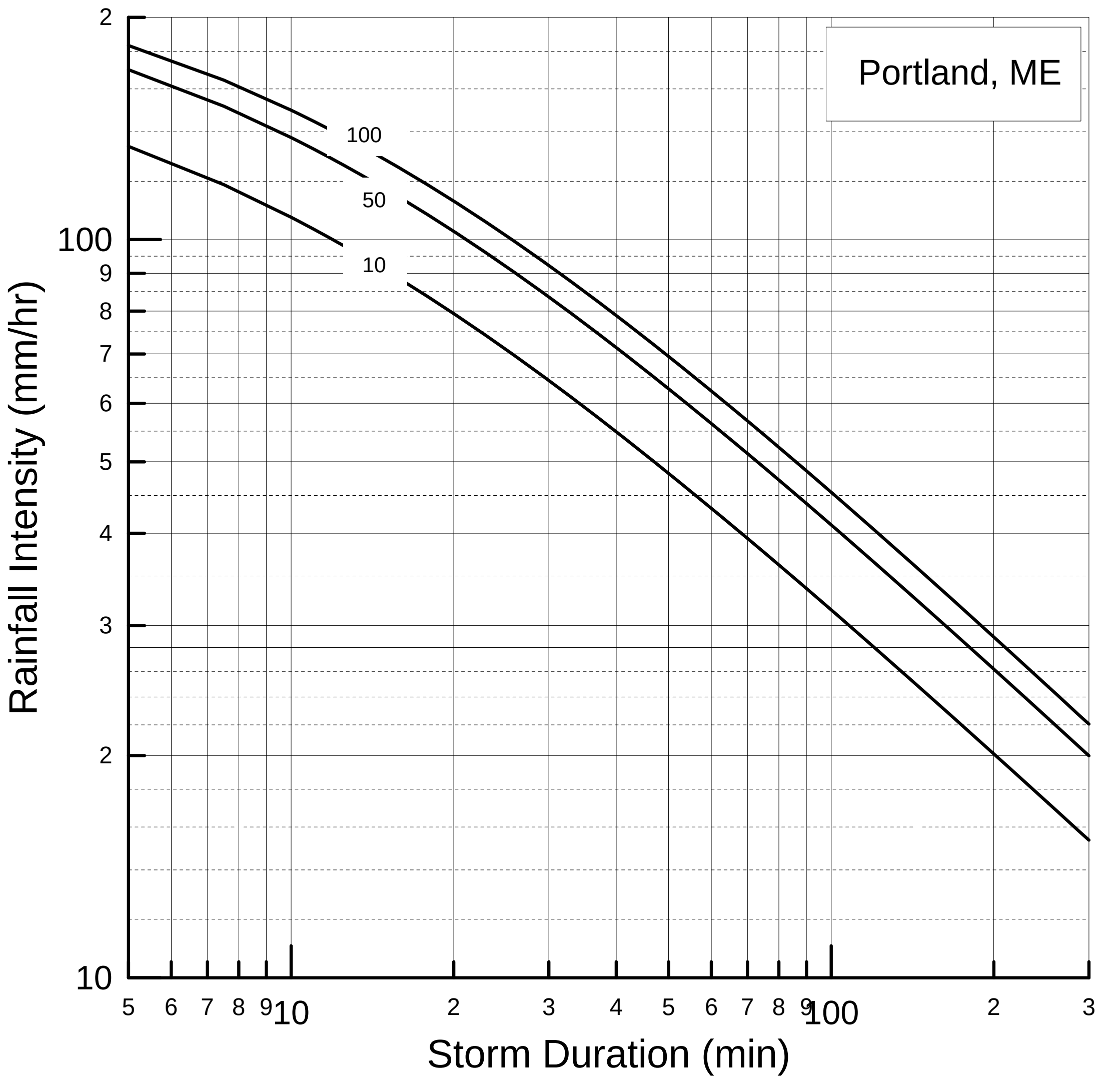


Figure 12-2.1b: Intensity-Duration-Frequency Curve, Portland, Maine (labeled return period in years).

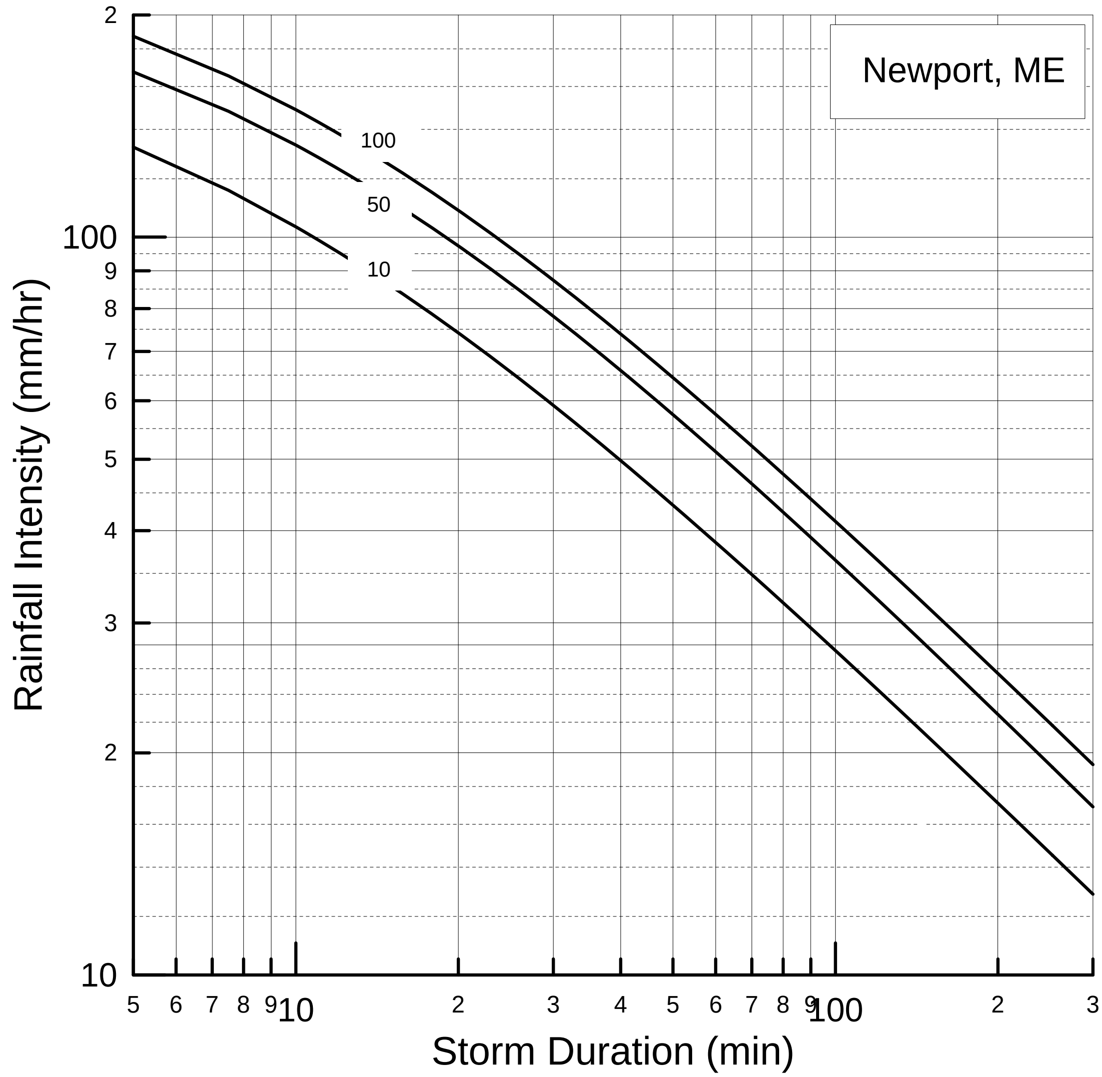


Figure 12-2.1c: Intensity-Duration-Frequency Curve, Newport, Maine (labeled return period in years).

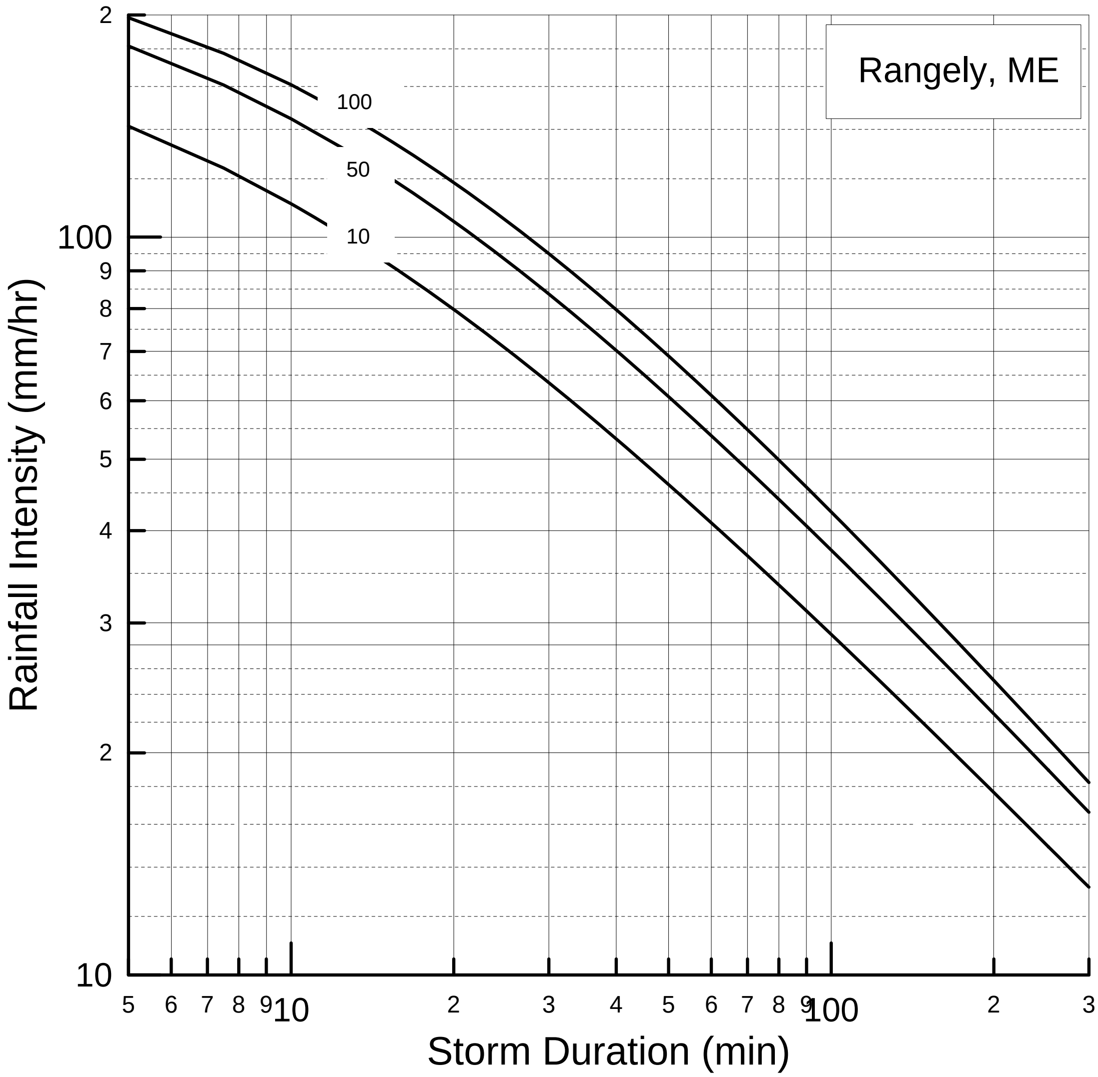


Figure 12-2.1d: Intensity-Duration-Frequency Curve, Rangely, Maine (labeled return period in years).

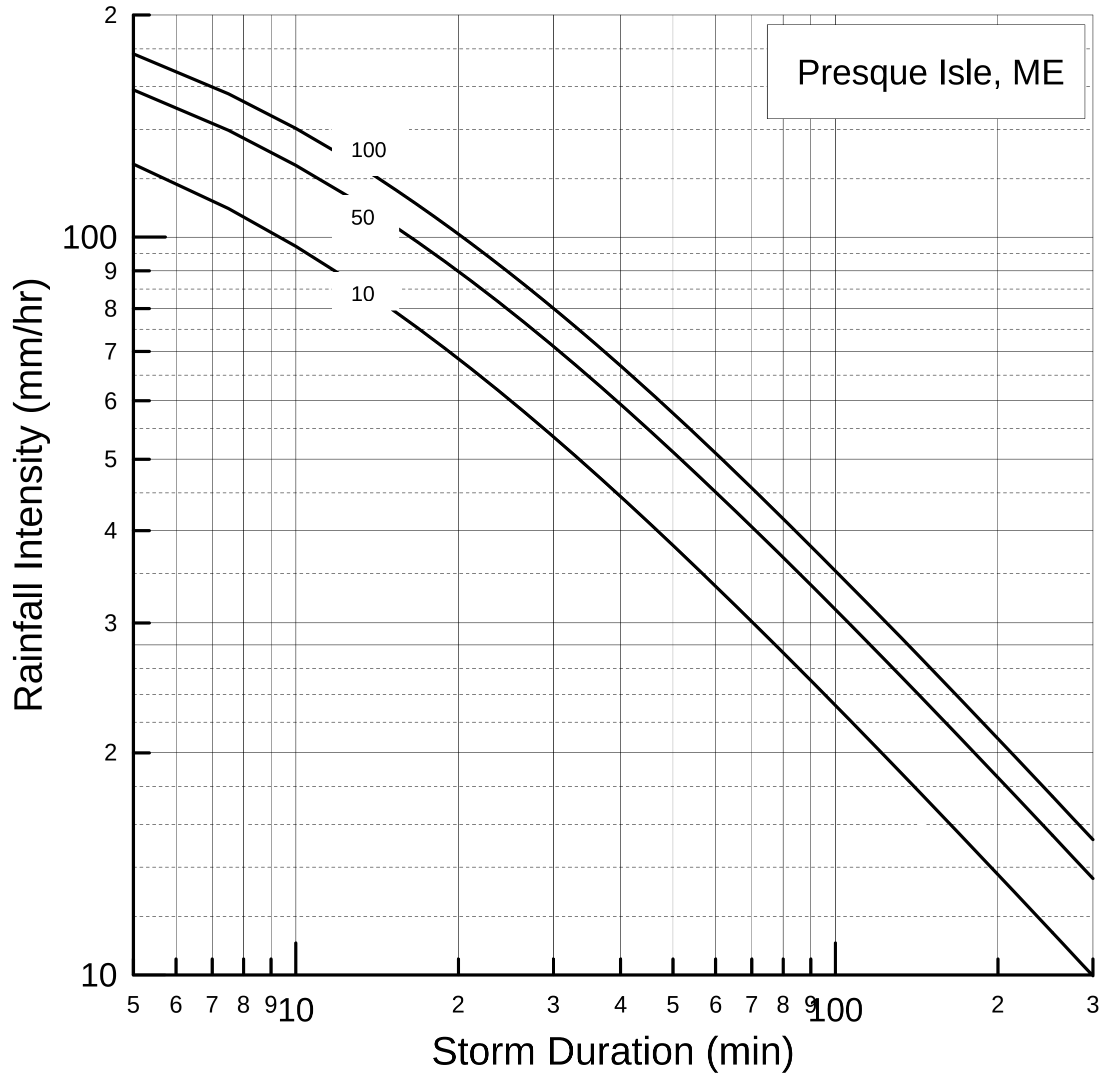


Figure 12-2.1e: Intensity-Duration-Frequency Curve, Presque Isle, Maine (labeled return period in years).

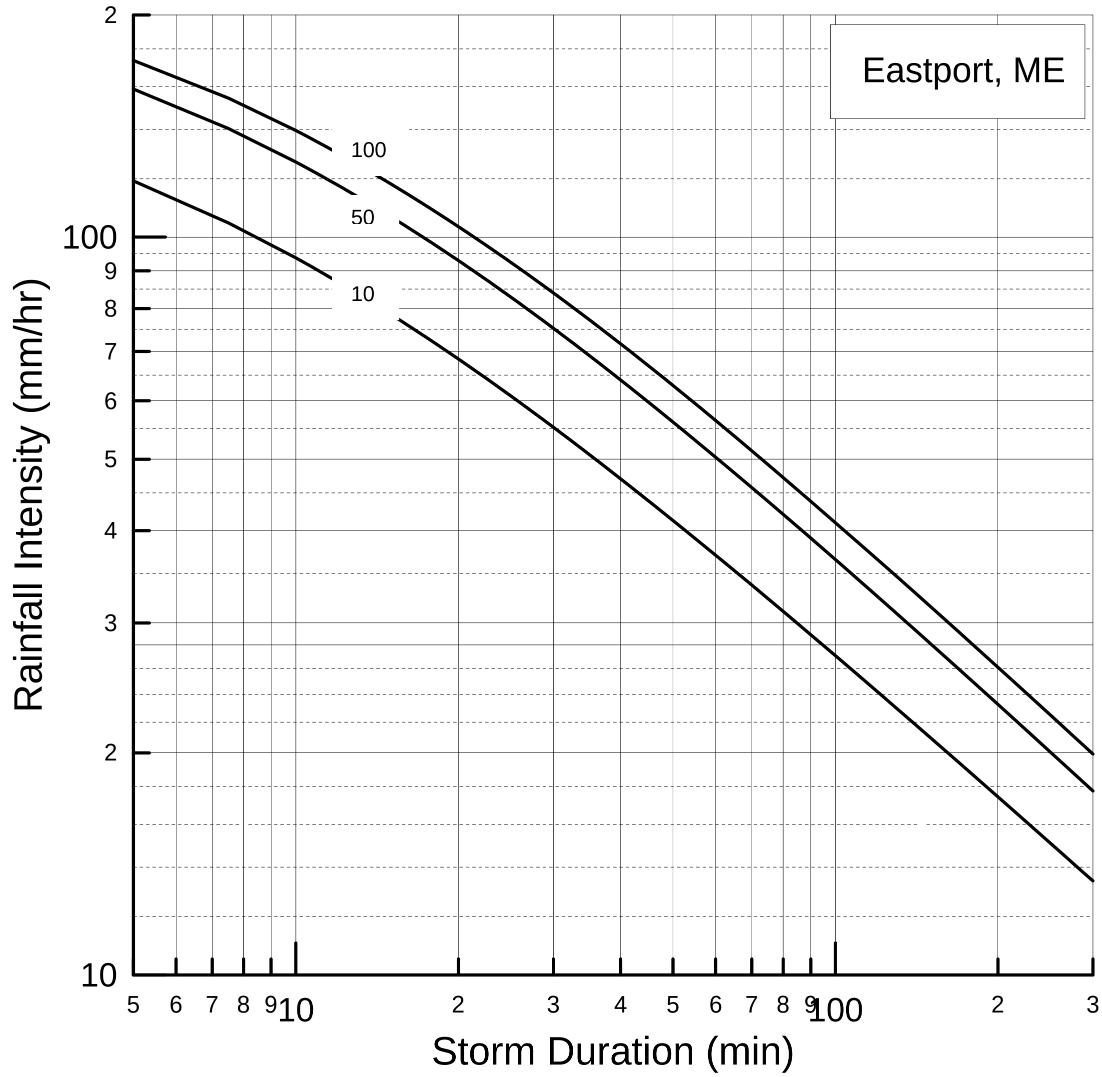


Figure 12-2.1f: Intensity-Duration-Frequency Curve, Eastport, Maine (labeled return period in years).

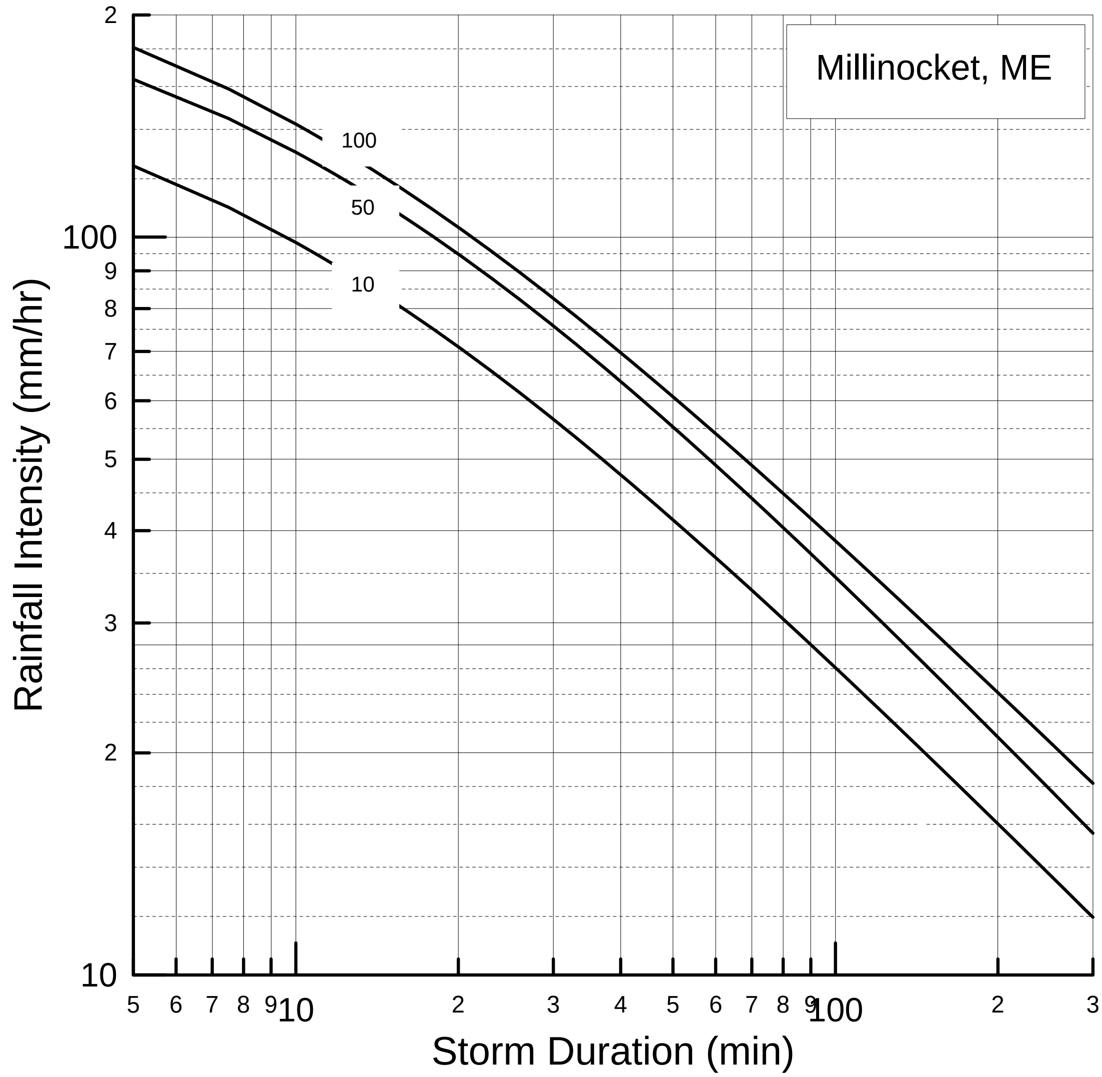


Figure 12-2.1g: Intensity-Duration-Frequency Curve, Millinocket, Maine (labeled return period in years).

Figure 12-4.1
Design Chart for Sizing Simple CMP Culverts Under Inlet Control

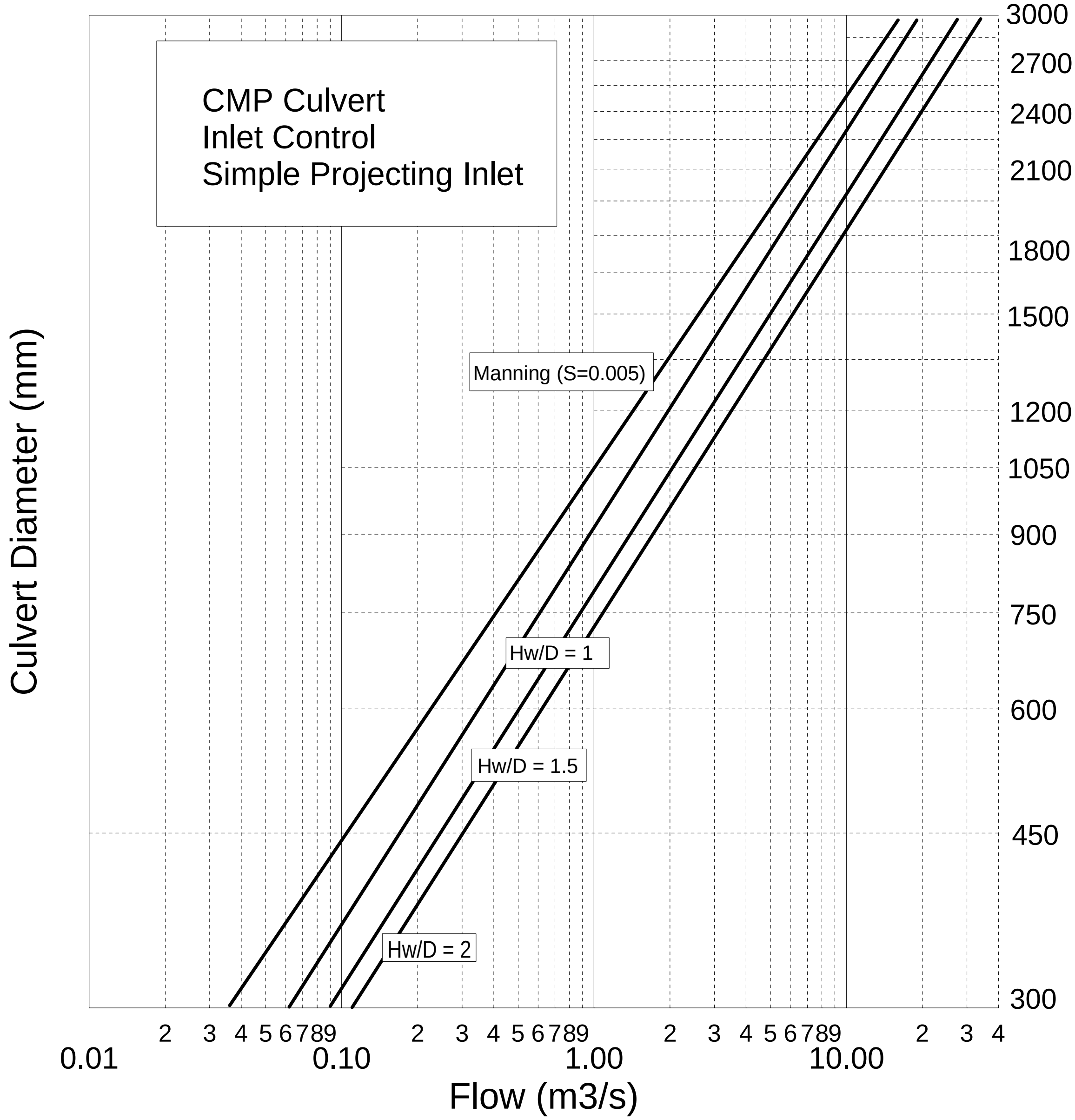
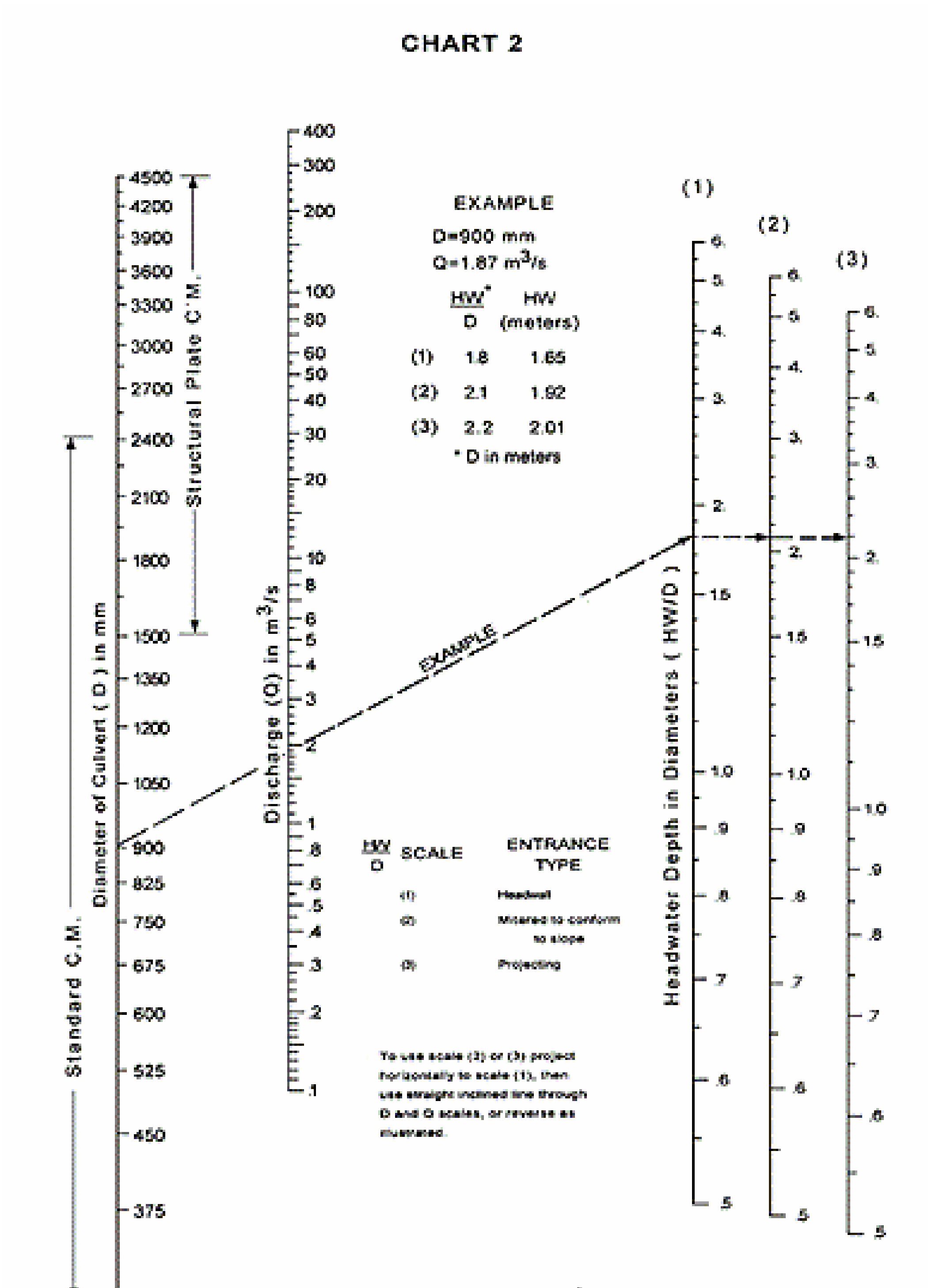


Figure 12-4.2
Design Chart for Sizing CMP Culverts Under Inlet Control



HEADWATER DEPTH FOR
C.M. PIPE CULVERTS
WITH INLET CONTROL

Figure 12-5.2a: Inlet Spacing for Simplified Design Scenarios (asphalt, no offsite runoff)

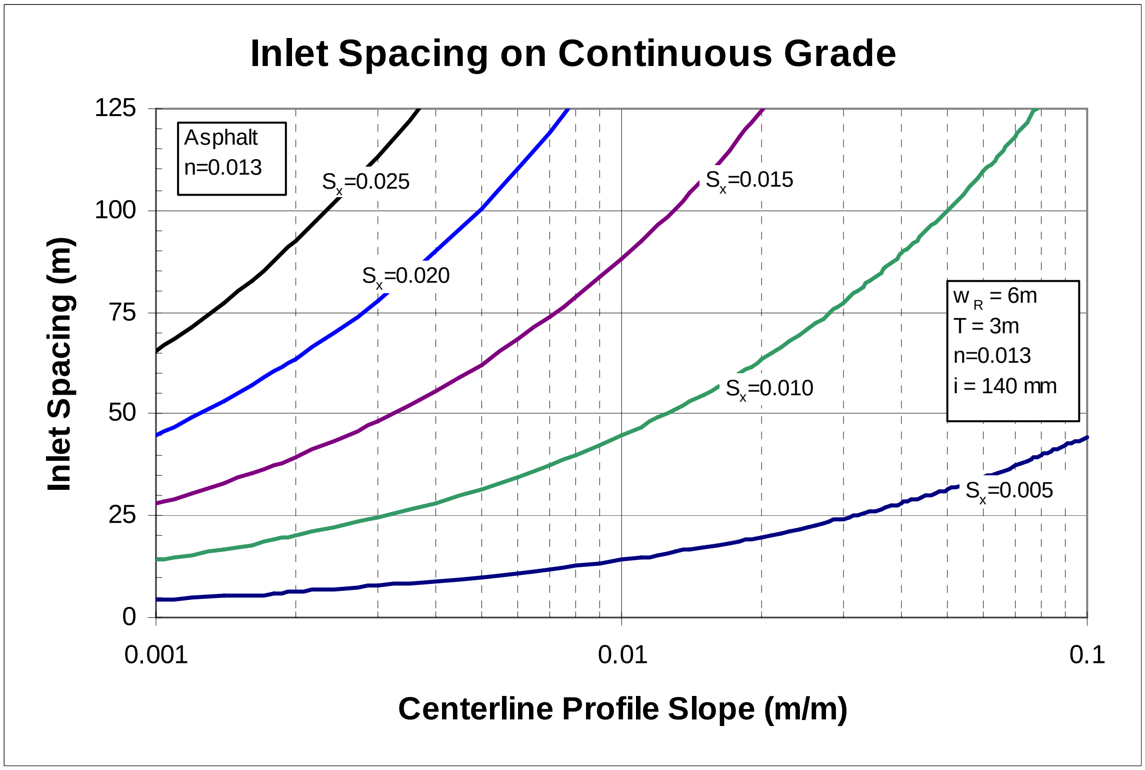


Figure 12-5.2b: Inlet Spacing for Simplified Design Scenarios (concrete, no offsite runoff)

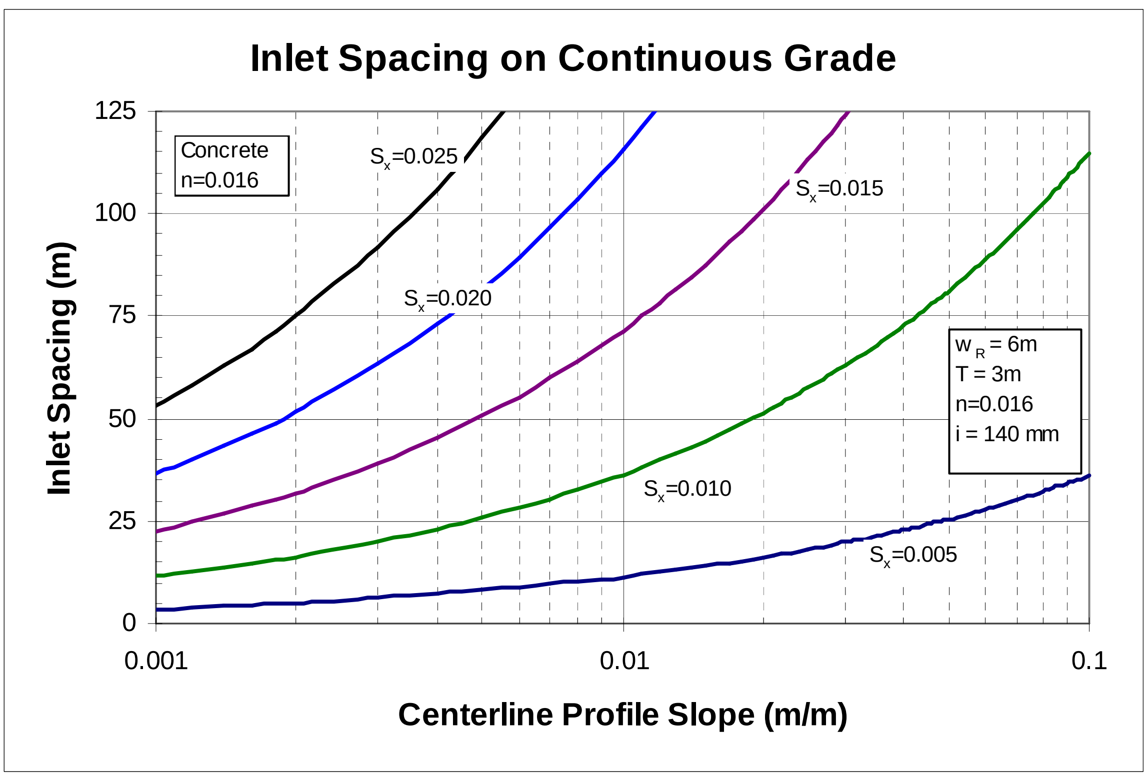


Figure 12-5.4: Circular Pipe Full Flow Geometric Functions

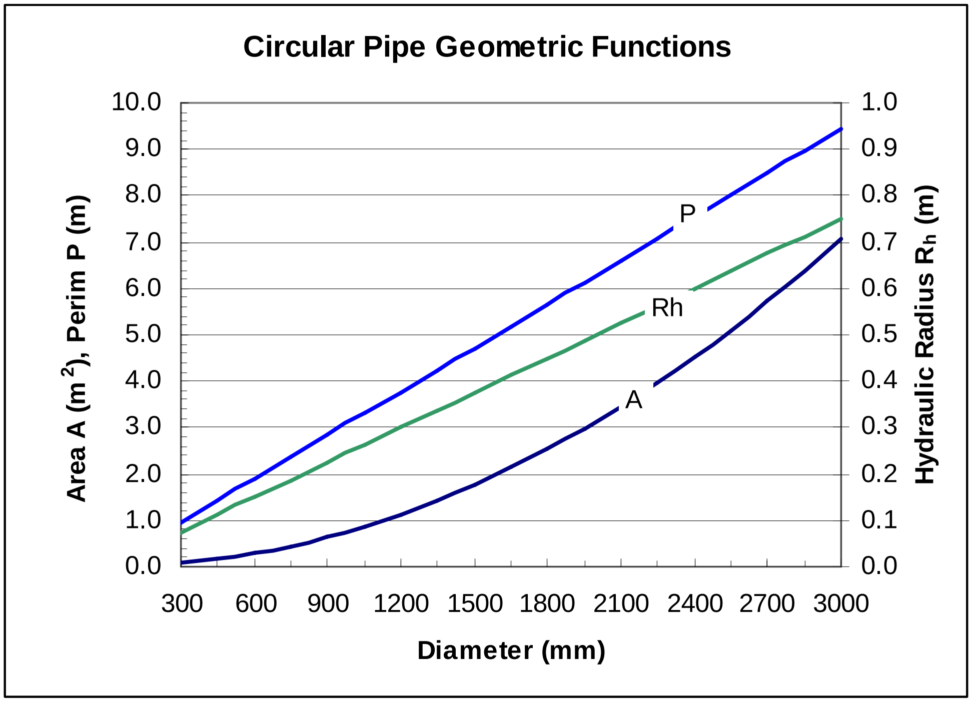
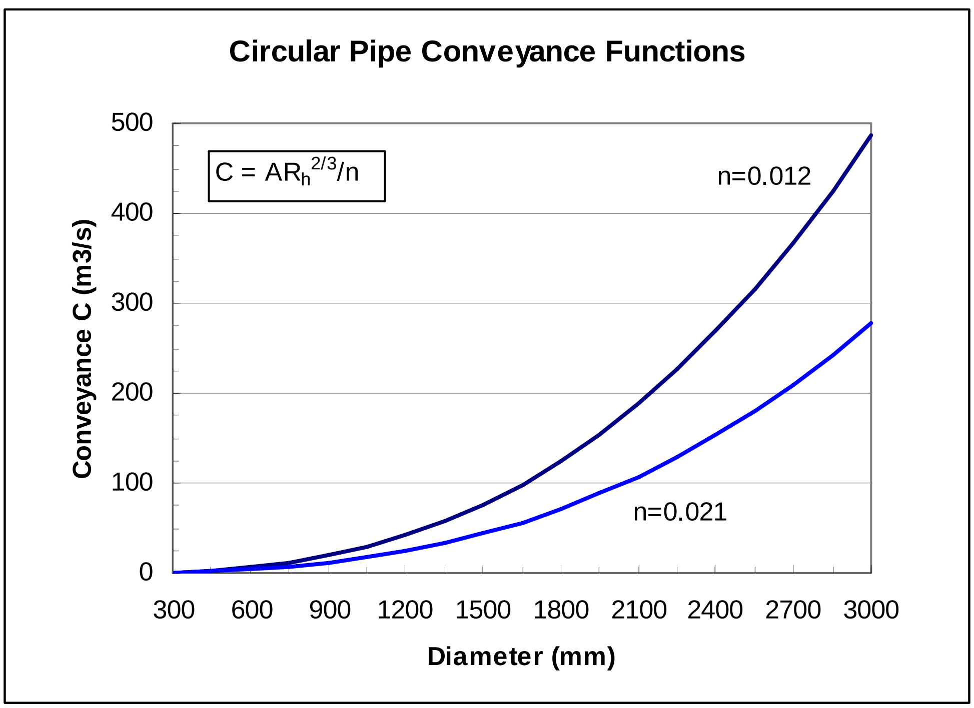


Figure 12-5.5: Circular Pipe Conveyance Function



CHAPTER THIRTEEN

FLEXIBLE PAVEMENT DESIGN

December 2007

Chapter Thirteen

TABLE OF CONTENTS

Chapter Thirteen

FLEXIBLE PAVEMENT DESIGN

13-1 INTRODUCTION

13-1.1 Purpose

This chapter will provide pavement design policies and guidance in order for the highway designer to effectively complete the pavement design on a given project. Effective pavement design begins with proper project scoping and includes pavement and roadway data collection and analysis, identification of alternative treatments and selection of the most economical treatment, as well as other steps described in this chapter. The basic information is provided here. For more detailed information please see the references and resources provided. A pavement design needs to be completed during the early phase of project development. This step ensures that pavement design is used to calculate project cost rather than project cost dictating pavement design.

13-1.2 Pavement Design History

In the late 1950's, AASHO (American Association of State Highway Officials) conducted tests on flexible and rigid pavements in Ottawa, Illinois to determine how traffic contributed to the deterioration of highway pavements. The information obtained was crucial in advancing the knowledge of pavement structural design, pavement performance, load equivalencies, climate effects, and much more.

The results from the AASHO road test were used to develop empirical equations to be used for the design of pavement structures and to develop structural pavement design guides, including the *AASHTO Guide for the Design of Pavement Structures.* MaineDOT currently uses the 1993 version of that guide for pavement design.

13-1.3 Flexible Pavement – Definition

A flexible pavement structure typically consists of layers of different materials that increase with strength as you move towards the surface (weakest layer on the bottom, strongest layer at the surface). A flexible pavement relies on a layered system to distribute traffic loads over the subgrade. The load carrying capacity of a flexible pavement is brought about by the load-distributing characteristics of each layer in the layered system. The layers of a flexible pavement structure typically consists of hot mix asphalt (HMA) at the surface, with a stabilized base, base course gravel, and/or subbase course gravel.

13-2 DATA COLLECTION FOR PAVEMENT DESIGN

The following sections contain information that can be collected early in the pavement design process to help determine the necessary scope of work and the treatment selection for the pavement structure.

13-2.1 Traffic Data

Traffic data is requested from the Bureau of Planning using the form in Figure 13-1. The information reported back to the pavement designer on the Traffic Data sheet includes AADT, truck volumes, and the 18-kip Equivalent values at P 2.0 and P 2.5. The 18-kip Equivalent value is needed to calculate the design ESAL's for the pavement design and FWD Analysis.

13-2.2 Pavement Management Section

Pavement distress data is collected on Federal and State owned roads on a two year cycle using an ARAN (Automated Road Analyzer). The data collected includes images of the roadway, pavement distresses such as rut depth and cracking, and ride quality information. This data is collected and managed by the Pavement Management Section in the Bureau of Planning. This data should be examined to identify existing pavement distresses. These distresses should always be verified with field checks and the appropriate investigations to determine best approach to mitigating those distresses.

13-2.3 Project History

All available historical information should be investigated before beginning the design of the pavement structure. The following are sources that can be used to find historical data for roadway projects:

- The Vault – The vault contains as-built plans for projects back as far as the 1940's. The usefulness of this information depends on what can be found and what type of project is being contemplated. Most of these plans have been scanned and are now available electronically via the E-Plans Archive on the MaineDOT Intranet page or at the following link: http://dot0dta1asiis03/plansweb/dpr.asp. The electronic as-built plans contain the plan views, typicals, notes and drainage sheets. Cross sections are available on microfiche film. The microfiche reels are located in the vault and the viewer is located in Room 419 at the Augusta office.
- TIDE - Project history information is available through TIDE. This information generally only goes back to projects done since 1990.
- Department Resources – Many construction and maintenance personnel have a long personal history with a particular area or road. Maintenance personnel are an excellent resource for gathering information on existing drainage, frost, or pavement problems.

13-2.4 Field Data

Subsurface information should be collected on all projects requiring a pavement design. The amount of subsurface information needed greatly depends on the scope and location of the project. The geotechnical team member can make recommendations for and coordinate the subsurface exploration program. Field information that should be considered for the pavement design includes:

- Falling Weight Deflectometer (FWD- for pavement condition and the Resilient Modulus
- Borings – to determine the soil types, layer thicknesses, and material properties
- Groundwater Elevations
- Subgrade Soil Type – to determine the anticipated foundation support for the pavement structure as well as construction equipment.
- Areas of Distress and Distress Type – Structural or functional distress
- Frost depths , Frost heave locations, Thaw weakening locations
- Existing aggregate quality – to determine if it meets MaineDOT Standard Specifications

13-3 PAVEMENT TREATMENTS

The Department utilizes a variety of different pavement treatments depending on the roadway facility and the work type associated with each facility. Roadway facilities include the Interstate, Urban Highways, Minor Collectors, and Rural Highways. Work types for each of these facilities include Development, Preservation, and Rehabilitation.

13-3.1 Highway Development

Development projects are those where there is a creation or substantial replacement of a transportation facility that results in a functional or structural upgrade. Development projects include new construction and reconstruction of a roadway. The pavement will be new for the full depth.

13-3.2 Highway Rehabilitation

Rehabilitation projects are those where the existing structural core of a facility is restored to a previous level of service. Pavement treatments for rehabilitation projects include recycling of existing materials, highway widening with an overlay, and structural overlays.

13-3.3 Highway Preservation

Preservation projects are those where the facility's functional or structural integrity and appearance is maintained. Pavement treatments for preservation projects include overlays, chip seals, crack sealing, Maintenance Surface Treatments (MST), microsurfacing, and mill and fills.

13-4 RECYCLING BITUMINOUS ASPHALT PAVEMENT

Recycling and reusing hot mix asphalt pavements can provide excellent engineering, economic, and environmental benefits for highway rehabilitation and reconstruction projects. In the recycling process, the existing hot mix asphalt of a structurally failed pavement is uniformly pulverized or processed and blended with asphalt binder or emulsion to produce a new, stronger, stabilized base course gravel.

For economic reasons, recycled materials should be considered first for the pavement design in all highway rehabilitation and reconstruction (full or partial) projects. Both asphalt and aggregate are a non-renewable resource, and as resources diminish, costs of these materials increase. The supply of suitable aggregate is rapidly being depleted in Maine. Many roadways were originally constructed with

valuable high quality aggregate, and since the Department owns all materials existing in our roadways, reusing these materials as part of the pavement structure design and construction is economical.

Recycling is also environmentally beneficial. Since it is a cold procedure, it reduces the quantity of material to be disposed of in landfills and saves on the energy needed to produce new roadway materials (fuel for mining, trucking, crushing, Hot Mix Asphalt Plants, etc.).

Another benefit of recycling is that many of the current recycling methods allow fewer traffic delays during the construction phase. Once the design densities have been achieved, traffic can immediately run on the recycled material. Using recycled material also means less maintenance for the contractor since the recycled material is more stable than granular material, thus resulting in lower costs for the maintenance of traffic during construction and a decrease in construction time.

MaineDOT has been using various recycling methods to create a stabilized base course gravel including Full Depth Reclamation with Foamed Asphalt, Full Depth Reclamation with Cement, Plant Mix Recycled Asphalt Pavement (PMRAP), and Cold-in-Place Recycled Pavement (CIPR).The selection of the most applicable recycling process depends on many factors including the size and location of the project, the amount of vertical and horizontal realignment, traffic volumes and ESALS, the material properties of the existing pavement structure, recycled material availability, and the required depth of recycled material to meet structural needs.

A summary of recycling methods and processes are described below. When designing a project, select a recycling method that is applicable to the majority of a project. Small quantities or short sections of a project are typically not cost effective for recycling. In the decision making process, consideration also should be given for overhead clearances, the roadway width needed for the equipment to perform the work, and maintenance of traffic during construction.

The designer also needs to be aware of the cost effectiveness of the individual methods as it pertains to the particular project being designed. The applications described below are general conditions which would dictate which process should be used and should be viewed as a guideline. There may be project specific reasons to use a method outside the conditions recommended, particularly on full reconstruction projects.

13-4.1 Full Depth Reclamation with Foamed Asphalt

The Foamed Asphalt stabilization process involves full depth reclamation of all of the existing hot mix asphalt (HMA) and some (usually 2”) of the underlying sub-base gravel, shaping this material to the desired grade and slope and compacting the material to specifications. Cement and/or crusher dust is added as per mix design, the material is reclaimed again to the desired depth being treated with expanded bitumen and water (expanded bitumen and water to be added in amounts as required by mix design), followed by final grading and compaction. This processed material then undergoes a curing period, followed by the placement of an HMA course. For a more detailed description of this work refer to Special Provision 309 and 108.

Foamed Asphalt recycling is generally used in the following conditions:

- the horizontal and vertical alignments of the road are to standards or minimal adjustments are needed

- the existing subbase is sufficient in depth, has a fine content (percent passing the #200 sieve) greater than 5%, and a Plasticity Index (PI) less than 10
- the existing drainage is adequate or drainage improvements will be part of the project design
- the existing pavement structure is deteriorated with extensive cracking, potholing, major deformation (rutting & shoving), raveling, and/or cross slope problems
- the existing HMA depth is sufficient to foam the depth of treatment to be specified.

Foamed asphalt treatments are typically 5 inches to 8 inches thick. Existing HMA depths should be collected during the design phase to determine the depth of the foamed asphalt treatment and for estimating purposes. These depths should also be provided in the contract documents for the bidders use.

13-4.2 Full Depth Reclamation with Cement

The cement stabilization process involves full depth reclamation of all of the existing hot mix asphalt (HMA) and some (usually 2") of the underlying sub-base gravel, shaping this material to the desired grade and slope and compacting the material to specifications. Cement and water are then added as per mix design, the material is reclaimed again to the desired depth being treated, followed by final grading and compaction. This processed material then undergoes a curing period, which includes microfracturing the recycled material to reduce shrinkage cracks, followed by the placement of an HMA surface course. For a more detailed description of this work refer to Special Provision 308 and 108.

Cement stabilization is generally used in the following conditions:

- the horizontal and vertical alignments of the road are to standards or minimal adjustments are needed
- the existing subbase is sufficient in depth, has a fine content (percent passing the #200 sieve) greater than 5%, and a Plasticity Index (PI) less than 10
- the existing drainage is adequate or drainage improvements will be part of the project design
- the existing pavement structure is deteriorated with extensive cracking, potholing, major deformation (rutting & shoving), raveling, and/or cross slope problems
- the existing HMA depth is sufficient to stabilize the depth of treatment to be specified.

Cement treatments are typically 5 inches to 8 inches thick. Existing HMA depths should be collected during the design phase to determine the depth of the cement treatment and for estimating purposes. These depths should also be provided in the contract documents for the bidders use.

13-4.3 Plant Mix Recycled Asphalt Pavement (PMRAP)

The PMRAP process involves removing the existing asphalt pavement, hauling it to a processing site, and processing the asphalt along with additives (cement, emulsified asphalt, and water) to meet mix design specifications. Once processed, the PMRAP material is hauled back to the project location, where it is placed t o the specified depth with typical paving equipment, and compacted to meet density requirements. This processed material then undergoes a curing period, followed by the placement of an HMA course. For a more detailed discussion of this treatment refer to Special Provision 310 and 108.

PMRAP is generally used in the following conditions:

- major adjustments to the horizontal and vertical alignments of the road are needed to meet standards
- the existing subbase is inadequate in depth or does not meet MaineDOT aggregate specifications; hence material needs to be added
- the existing drainage is adequate or drainage improvements will be part of the project design
- the existing pavement structure is deteriorated with extensive cracking, potholing, major deformation (rutting & shoving), raveling, and/or cross slope problems
- the existing HMA depth is sufficient to supply the specified depth of PMRAP the full width of the roadway, including the shoulders, or additional RAP material is available to supplement the need.

Recommended PMRAP depths are 3", 4", 5" and 6". Lifts of more than 4" must be done in two layers. Existing HMA depths should be collected during the design phase to determine the appropriate PMRAP thickness and for estimating purposes. These depths should also be provided in the contract documents for the bidders use.

13-4.4 Cold-in-Place Recycled Pavement (CIPR)

The Cold-in-Place recycling is completed with a rolling train consisting of equipment that will remove, size, mix, place, and compact the processed material to meet design requirements. The equipment in the CIP rolling train includes a Cold Milling Machine, a screening and sizing unit, a portable mixing unit, a paver, and vibratory and pneumatic tire rollers. This process consists of 1) milling 3 to 5 inches (70% to 80%) off the existing bituminous pavement, 2) pulverizing and sizing the millings, 3) mixing the millings with emulsified asphalt, water and cement as per mix design requirements, and 4) placing and compacting the mixture to the specified grade and density. An HMA surface layer is placed following a minimum curing period of four days.

CIP is generally used in the following conditions:

- no adjustments to the horizontal and vertical alignments of the road are needed
- the existing subbase is adequate in depth meets MaineDOT aggregate specifications
- the existing drainage is adequate or drainage improvements will be part of the project design
- the existing pavement structure is deteriorated with extensive cracking, potholing, major deformation (rutting & shoving), raveling, and/or cross slope problems
- only minor adjustments are needed to correct the cross slope.

Existing HMA depths should be collected during the design phase to determine the depth of the HMA and for estimating purposes. These depths should also be provided in the contract documents for the bidders use.

.

13-4.5 Weather Limitations

When any recycling method is used, work shall be performed when:

- Foaming operations will be allowed between May 15th and September 15th inclusive in Zone 1 (areas north of US Route 2 from Gilead to Bangor and north of Route 9 from Bangor to Calais). Foaming operations will be allowed between May 1st and September 30th inclusive in Zone 2 (areas south of Zone 1 including the US Route 2 and Route 9 boundaries).
- The atmospheric temperature is 50° F and rising.

- When there is no standing water on the surface.
- During generally dry conditions.
- When the surface is not frozen and when overnight temperatures are expected to be above 32° F.
- Wind conditions will not adversely affect the operation.

13-4.6 Curing

All recycling methods have a period of time, called a curing period, where no new HMA shall be placed until a curing period has elapsed. The curing period for all recycling methods is different (see the Special Provisions for specific information). Cold weather, damp weather, rain, and freeze-thaw cycles can severely damage the recycled material and affect the curing process. Before selecting a recycling method, the construction schedule should be carefully considered to ensure that the recycling process does not affect the anticipated construction schedule.

13-4.7 Design

The following table can be used by the Designer as a tool for the preliminary selection of the recycling method that best applies to the project scope and location. To be cost effective, the selection should be based on the recycling method that is applicable to the majority of a project. There may be project specific reasons to use a method other than what is recommended, particularly on full reconstruction projects, projects where a significant depth of HMA is required to meet the design structural requirements, or the existing HMA is extremely thick. Recycled material should be placed the full width of the roadway for all the mentioned recycling methods. A 3 inch minimum HMA wearing course is recommended over all recycled materials. The actual wearing course thickness can be determined using the design method in section 13-6, Pavement Design.

The designer should make a preliminary determination whether or not recycled materials will be used and which recycling technique may be appropriate early enough in the life of the project to allow time for a design to be done. Samples of existing material will be taken and tested by the Bangor Lab to produce a mix design for the project prior to advertisement.

Criteria	FDR w/Foamed Asphalt or Cement	PMRAP	CIPR
If major alignment adjustments are needed		√	
If existing subbase depth is adequate	√		√
If existing subbase meets specifications	√		√
If the existing drainage is adequate or will be improved	√	√	√
If the existing pavement is deteriorated	√	√	√
If there is macadam present		√	
If there is penetrated gravel present	√	√	√

Criteria	FDR w/Foamed Asphalt or Cement	PMRAP	CIPR
Structural Coefficient for design	**.26 to .32**	**.26 to .32**	**.26 to .32**
Depth of recycled material	**5 to 6 inches**	**3 to 6 inches** (greater than 4 inches requires 2 lifts)	**70 – 80% of existing HMA layer**

(√-indicates process is suited for)

13-5 FROST CONSIDERATIONS

Frost action can cause damaging effects to pavement structures in cold climates and in turn reduce the long term performance and increase roadway maintenance costs. Frost action can produce differential heaving, cracking, a rough and irregular surface, blocked drainage during the freezing or frozen period, and a reduction in bearing capacity during the thawing period.

Frost heaving is caused by the formation of ice lenses in the soils within or beneath the pavement structure. In order for frost heaves to develop, the following three conditions must exist: 1) there are frost susceptible soils present to the depth of frost penetration, 2) there is an available source of water from below that can be drawn up to the freezing front (capillary rise), can infiltrate into the pavement through cracks in the asphalt or unpaved shoulders, and/or move laterally into the freezing zone, and 3) there are temperatures below freezing for an extended period of time. If one of these conditions can be eliminated, frost heaving will not occur. Frost heaves are most often located at:

- Transitions from cut to fill
- Areas with shallow ledge transitions to frost susceptible soils
- At culvert pipes
- Areas where ditches and/or underdrain are inadequate or non-existent
- Areas adjacent to driveways that dam roadside ditches and/or collect water

Thaw weakening occurs during the thawing period when the underlying soils are saturated or supersaturated due to the increase in water content from melting ice lenses. Soils become significantly weaker and unable to support traffic loads when in a saturated condition.

Thawing generally takes place from the surface downward underneath pavements, with the rate of thaw dependent on the pavement surface temperature and air temperature. Thermal energy allows the heating of the black asphalt layer resulting in higher surface temperatures and a rapid melting of the ice lenses in the upper soils. This type of thawing produces adverse drainage conditions since the melted ice water becomes trapped between the asphalt surface layer and the underlying frozen layer. Therefore, the only means of drainage is laterally or through the surface. If the shoulders remain frozen because of thermal differences between vegetated shoulders and the asphalt or the insulating effects of snow cover, lateral drainage may be restricted.

Water that is trapped between the asphalt surface and underlying frozen soil is “squeezed” when traffic loads are applied. Very high water pressures can develop and cause destructive forces to be exerted on the bottom of the asphalt layer. If cracking is present in the asphalt layer, water pressure can be released by a mechanism known as pumping. Pumping is the ejection of water and fine materials under

pressure from applied traffic loads through surface cracks. As the water is ejected through the cracks, it carries fine subbase material out with it, resulting in progressive loss of subbase material. Eventually enough subbase material will be lost that pavement deterioration will occur due to lack of support for traffic loads. Areas visible on the surface of the pavement that appear wet or have the accumulation of subbase material close to crack locations is evidence of pumping.

13-5.1 Design Information

The need for protection against frost action should be determined in the preliminary design phase for roadway projects. Information is collected by the geotechnical team member to determine frost susceptibility, followed by recommendations to the highway designer in the Preliminary Design Report for appropriate methods of frost mitigation. Information that needs to be collected includes field locations where frost problems exist, areas with moderate to severe pavement deterioration, the depth to the groundwater table, the depth of frost penetration, soil type and its measure of frost susceptibility, and locations where there are changes in soil type or ledge.

13-5.1.1 Site Inspection

Areas where frost problems occur should be identified during the freezing and thawing periods. The team geotechnical member or pavement designer should conduct a frost survey periodically to collect and record information at:

- Locations of frost heave (cross pipes, soil type changes)
- Locations with pavement cracking, where there is a rough and irregular ride, and pavement breakup
- Locations where pumping is evident
- Locations with significant rutting during thawing
- Locations where drainage appears to be blocked

13-5.1.2 Subsurface Investigations and Soils Classification

Subsurface investigations for frost design considerations should include the collection of subsurface information to determine soil types, the soil profile, location of the groundwater table, and the soil index properties necessary for frost classification. The geotechnical team member will request the subsurface investigations and laboratory testing necessary to determine frost susceptibility rating. Frost ratings range from zero (non-frost susceptible), to Class IV (highly frost susceptible). The pavement designer can find the soil classifications and frost susceptibility ratings on the MaineDOT Laboratory Testing Summary Sheet typically included in the Preliminary Geotechnical Report.

13-5.1.3 Design Freezing Index and Frost Depth

Depth of freezing is determined by the rate of heat loss from the soil surface. Heat loss depends on the thermal properties of the soil, and climatic variables such as solar radiation, snow cover, wind, and air temperature.

Air temperature records from the State of Maine can be used to gauge the severity of ground freezing by using the degree-day concept. The Design Freezing Index is simply the accumulated total of degree-

days of freezing for a given winter. Figure 13-2 illustrates the Maine Design Freezing Index that can be used to determine the depth of frost for design.

Correlations between frost depth and Freezing Index can be useful as guides for estimating total frost depth. Figure 13-3, developed by the Army Corps of Engineers, can be used to get a general and approximate depth of frost for the project location based on soil type and surface conditions.

EXAMPLE 1: Depth of Frost
Project location: Gray, Maine
Subgrade soil: Sand and Gravel

From Figure 13-2, the Design Freezing Index is approximately 1350. From Figure 13-3, using a DFI of 1350, Pavement-Snow Free, and the plot for Granular soil, the depth of frost penetration is 72 inches.

13-5.2 Mitigating Frost Action

By eliminating one of the three conditions necessary for frost action to develop in roadways (the presence of frost susceptible soils, an available source of water, and an extended period of freezing temperatures), frost heaves and thaw weakening will not occur. By reducing or eliminating frost action under roadways, the life of the pavement structure will be extended and maintenance costs will be greatly reduced. Frost heaving is most damaging to a pavement when the heave is differential. A uniform heave will not damage the pavement. However, regardless if heaving is uniform or differential, thaw weakening can develop if the above conditions exist. Thaw weakening is more significant in some soil types than others and will be most destructive under heavy traffic loads.
The following are methods that can be used to mitigate frost action. Not all of the methods eliminate frost action, but offer a reduction in frost damage to the pavement structure. The Highway Designer should discuss these methods with the project geotechnical engineer or geologist to determine the best solution for site conditions and those that will be within budget constraints.

13-5.2.1 Frost Heaving

- Increase the depth of the pavement section. A thicker pavement section will limit the depth of frost penetration into the subgrade.
- Remove and replace highly susceptible soils to the depth or reduced depth of frost penetration. A reduced depth design approach limits the depth of frost penetration into the subgrade. This reduced depth can be determined using various design charts correlated with soil properties.
- Provide adequate drainage to lower the groundwater table and remove surface water.
- Provide transition zones between frost susceptible and non-frost susceptible soils, including ledge
- Provide transition zones between frost susceptible and non-frost susceptible soils at culvert locations.
- Provide a capillary break within the depth of frost penetration. A stone layer or drainage geotextile can be placed within or below the frost zone to interrupt the flow of water from the groundwater table to the freezing front.
- Pave roadway shoulders to reduce water infiltration from the surface.

- Use insulating materials to reduce or eliminate frost penetration below the pavement. If heat loss can be prevented or reduced, frost-susceptible soils may not experience freezing temperatures.

13-5.2.2 Thaw Weakening

- Design the pavement structure based on a reduced subgrade resilient modulus. This method simply increases the pavement thickness to account for the damage and loss of support caused by frost action.
- Provide adequate drainage to lower the groundwater table and remove surface water.
- Restrict pavement loading during thaw conditions when the subgrade support is weak.
- Chemically stabilize certain subgrade soil types to the depth or reduced depth of frost. Chemical stabilization will reduce the water content and thaw recovery time.
- Incorporate a geotextile into the pavement design to give the structure added strength during thawing conditions.
- Use a select base course material such as crushed stone or another dense graded aggregate directly below the asphalt layer that will provide rapid drainage and will not experience a reduction in strength when saturated.

13-6 PAVEMENT DESIGN

The following sections give the pavement designer guidance for the design variables, performance criteria, material properties for structural design, and structural characteristics needed to complete pavement designs using the AASHTOWare DARWin 3.1 (Pavement Design, Analysis and Rehabilitation for Windows) software.

13-6.1 Design Software

MaineDOT designs flexible pavement structures using the AASHTOWare DARWin 3.1 (Pavement Design, Analysis and Rehabilitation for Windows) software. This software was developed from the design procedures in the 1993 AASHTO Guide for the Design of Pavement Structures. DARWin 3.1 allows designers to quickly produce pavement designs and compare alternative designs. This software is located at \\Dot0dta1fsaug01\$com-design\Darwin31.

13-6.2 Pavement Structure Thickness

The DARWin program is based on data extrapolated from the AASHO Road Test where pavement structures of about 26 to 28 inches of combined pavement, base and subbase aggregate were used. To account for Maine’s climate and to fall within reasonable limits of the extrapolated AASHO data, MaineDOT should generally design pavement structures comprising approximately 30 inches of pavement, base and subbase aggregates. There may be situations where different pavement structure thicknesses would be acceptable.

13-6.3 Structural Number Design - Input Variables

In the AASHTO design procedure, the pavement design calculation produces a structural number. That structural number expresses the structural strength of a flexible pavement. This value, which is the output of the AASHTO design equation, is then used to determine the individual layer thicknesses.

The structural number represents the ability of a flexible pavement to withstand structural loadings. Using the DARWin program , the "Calculate SN" option is used for pavement design. In this mode, given ESALs, initial serviceability, terminal serviceability, reliability level, overall standard deviation, and resilient modulus, a design (SN) can be calculated. The design SN is then used to design the pavement layers using the "Thickness Design" option in the "Design" pull-down

The values and interpretation for each specified design input presented in the succeeding paragraphs represent MaineDOT practice which is consistent with the 1993 AASHTO Guide for Design of Pavement Structures and regional pavement design procedures. The AASHTO design guide discusses the range of values in greater detail. The DARWin program uses the following input variables:

- 18-kip ESALs Over Design Period
- Initial Serviceability
- Terminal Serviceability
- Reliability Level (%)
- Overall Standard Deviation
- Subgrade Resilient Modulus (psi)
- Stage Construction
- Layer Coefficients

13-6.3.1 18-kip ESAL's Over Design Period

The design 80-kN (18-kip) ESAL applications are the cumulative number of 80-kN (18-kip) ESALs that the pavement is expected to carry over its initial performance period (the time from opening to traffic until major rehabilitation).

Traffic data to use for pavement design is requested from the Traffic section in the MaineDOT Bureau of Planning. This group estimates the projected daily 18-kip ESALs based on traffic counts, weigh-in-motion station data, and other traffic experience local to the project. The traffic estimates are provided as daily counts for both 2.5 and 2.0 terminal serviceability.

For example, the Traffic group estimates 274 daily 18-kip ESAL's for a terminal serviceability of 2.5 and the project design life is 20 years. The DARWin traffic volume input is:

Example:
(ESAL's P $_{2.5}$) x (#days per year) x (design life)
(274) x (365 days/year) x (20 years) = 2,000,020 ESAL's

13-6.3.2 Initial Serviceability

Initial serviceability is a measure of the pavement's smoothness or rideability immediately after construction. Serviceability is rated on a scale of 0.0 to 5.0, with 5.0 being a perfectly smooth pavement and 0.0 being a very rough or impassable pavement. In most cases, the initial serviceability of a new pavement should be above 4.0.

The design Initial Serviceability value used by MaineDOT is 4.5.

13-6.3.3 Terminal Serviceability

Terminal serviceability is the minimum tolerable serviceability of a pavement, on the same 0.0 to 5.0 scale. When the serviceability of a pavement reaches its terminal value, rehabilitation is required. In contrast to initial serviceability, which is measured or based on construction records, terminal serviceability is a function of many factors, including pavement classification, traffic volume, and location. Typical terminal serviceabilities are between 2.0 and 3.0, depending upon the functional classification of the roadway. AASHTO’s recommendations for the selection of the terminal serviceability are:

High Volume (> 10,000 ADT):	3.0 - 3.5
Medium Volume (3000 - 10,000 ADT):	2.5 - 3.0
Low Volume (< 3000 ADT):	2.0 - 2.5

The design Terminal Serviceability used by MaineDOT is 2.5 or 2.0, depending on traffic volumes and roadway classification (2.5 for higher traffic and higher classifications, 2.0 for lower traffic or lower classifications).

13-6.3.4 Reliability Level (%)

The inclusion of a reliability input in the pavement design process is a means of addressing variability. As defined by the AASHTO Design Guide, reliability (R) is the probability (expressed as a percentage) that a pavement structure will survive the design period traffic. Generally, as traffic volumes become larger, the consequences of premature pavement failure increase dramatically; therefore, high-volume roadways must be constructed with a much higher level of reliability than low-volume roadways.

The design reliability levels used by Maine DOT based on the roadway functional classifications are as follows:

Functional Classification	**AADT**	**Reliability Level %**
National Highway System		95
Interstate		95
Freeway		95
Functional Classification	**AADT**	**Reliability Level %**
Principal Arterial	> 15000	95
Minor Arterial	< 15000	90
Major Collector	6000 - 8000	90
Minor Collector	1000 - 6000	90

Functional Classification	AADT	Reliability Level %
Minor Collector	≤ 1000	85
Local	100 - 500	80

13-6.3.5 Overall Standard Deviation

The overall standard deviation accounts for all error or variability associated with design and construction inputs, including variability in material properties, roadbed soil properties, traffic estimates, climatic conditions, and quality of construction. Ideally, these values should be based on local conditions; however, in the absence of other values, the AASHTO Design Guide does provide recommended values. For the case where the variance of projected future traffic is not considered, the AASHTO Design Guide recommends a value of 0.44. In situations where the variance of projected future traffic is considered, a value of 0.49 is recommended.

The two different values reflect the designer's confidence in the projected ESALs. If there is strong confidence in the ESAL calculation, then the lower value of 0.44 should be used. Because the overall standard deviation incorporates all of the design variability, average values for all material properties and other design inputs should be used.
The Overall Standard Deviation used by MaineDOT is 0.45 for all projects.

13-6.3.6 Subgrade Resilient Modulus (M_R)

The resilient modulus is the material property used to characterize the support characteristics of the roadbed soil in flexible pavement design. In general terms, it is a measure of the soil's deformation in response to repeated (cyclic) applications of loads much smaller than a failure load.

The AASHTO design procedure requires the input of an effective roadbed soil resilient modulus. This effective resilient modulus is a means of representing the combined effect of all the seasonal modulus values by a type of weighted average.

MaineDOT calculates the subgrade resilient modulus to use for pavement designs by analyzing deflection data collected with a Falling Weight Deflectometer (FWD) with the DARWin software, and then applies a correction factor to account for seasonal variability. In some cases, such as a new alignment, it is not possible to obtain the resilient modulus with the FWD. Also, if there are underground utility trenches in urban areas or a rigid pavement below the HMA surface layer, resilient modulus values will not be representative of the actual subgrade soils. In these cases, the resilient modulus can be estimated by correlating the existing subgrade soil types to resilient modulus values based on soil type and their related soil support value. The FWD analysis that includes the resilient modulus values is typically requested from the project geotechnical engineer or geologist.

When the resilient moduli from the FWD analysis vary at every test location, the resilient modulus (M_R) to be used in the pavement design can be calculated using the 75th or 85th percentile of the field values. Field M_R values lower that 3000 psi and higher than 8500 psi can be eliminated from the calculations. In sections where the M_R is lower than 3000 psi, there are probably poor subgrade soils or drainage conditions. Improvements should be made to the subgrade or drainage at these locations. M_R values higher than 8500 typically indicate the presence of ledge.

The formulas to use in a Microsoft Excel spreadsheet are:

75th percentile	**85th percentile**
=ROUND(PERCENTILE(AX:AXX,0.25),-1)	=ROUND(PERCENTILE(AX:AXX,0.15),-1)

13-6.3.7 Number of Construction Stages

Regardless of the structural capacity of some pavements, there may be a maximum performance period associated with a given initial structure subjected to significant levels of heavy truck traffic. If this performance period is less than the analysis period, there may be a need to consider staged construction or planned rehabilitation in the design analysis. Staged construction is also appropriate when the structure that is needed to carry the projected traffic cannot be constructed for economic reasons.

At this time, the MaineDOT does not use the staged construction approach for pavement design. A value of 1 is used for pavement design.

13-6.4 Specified Thickness Design Method

Using the DARWin software, the Specified Thickness Design method allows the direct input of layer thicknesses, structural coefficients, and drainage coefficients in order to satisfy the structural number requirement of a flexible pavement. In this case, the program will not calculate layer thicknesses, but rather will allow the user to input any number of combinations to satisfy the design structural number requirements. The sum of the SN of the individual layers should be equal to the design SN. This is an iterative process, therefore the pavement designer will likely go through a process of trial and error in order to make the design SN equal to the calculated SN.

13-6.4.1 Structural Layer Coefficients

The MaineDOT uses the following layer coefficients for pavement design inputs:

Hot mix asphalt (HMA), top 4 inches maximum	0.44
Hot mix asphalt below top 4 inches	0.34
Aggregate subbase course gravel (Type D/E)	0.09
Base Course Gravel (Type A or B, crushed or screened)	0.12
Dense-Graded Aggregate	0.14
Recycled Materials	See Figure 13-4

13–6.5 Pavement Design Resources

The following is a list of resources that the pavement designer can use to obtain pavement design information:

- AASHTO Guide for Design of Pavement Structures
- Highway Program Support Unit

- MaineDOT/ACM Pavement Subcommittee Members
- Materials, Testing, and Exploration Section
- MaineDOT library
- Basic Asphalt Recycling Manual
- Other State DOT's pavement design manuals (most available online)
- Pavement Management Section in the Bureau of Planning

13-7 HOT MIX ASPHALT (HMA)

The major function of the HMA surface layer is to provide structural support, but it must also be able to resist traffic forces, limit the amount of surface water entering into the pavement structure, be skid resistant, and provide a smooth riding surface. The long term success of the surface course depends on the quality of the mix design, the environmental factors at the time of laydown, and that each HMA lift is properly compacted.

The following sections give the pavement designer guidance for the selection of HMA layer thicknesses.

13-7.1 HMA Layer Thicknesses

Recommended pavement depths per nominal aggregate sizes should be as follows:

Nominal Aggregate Size	Layer	Recommended Layer Thickness
4.75 mm	shim layers, variable depth	0" to 1½"
9.5 mm-fine	shim layers, variable depth	½" to 2"
12.5 mm-fine	shim layers, variable depth	¾" to 3"
12.5 mm-coarse	shim layers, variable depth	1" to 3"
9.5 mm-fine	surface layers, uniform depth	¾" to 1¼"
9.5 mm-coarse	surface layers, uniform depth	1¼" to 1½"
12.5 mm-fine	surface layer, uniform depth	1½" to 1¾"
12.5 mm-coarse	surface layer, uniform depth	1½" to 2"
12.5 mm-coarse	base layer, uniform depth	1¾" to 3"
19.0 mm-fine	base layer, uniform depth	2" to 3"
19.0 mm-coarse	base layer, uniform depth	2¼" to 3"

The layer thicknesses may be modified depending on the level of the HMA mix design (50 gyration mix, 75 gyration mix, or 100 gyration mix). 50 gyration mixes may be able to be placed in slightly thinner lifts.

13-7.2 Weather Limitations

When advertising a project and late season paving is expected, the thickness and gradation of the HMA is a very important consideration. A 12.5 mm graded HMA mix should be required for any course if the final surface layer is not placed prior to the required paving deadline. Thin layers of base or

binder courses will cool off quickly in late season paving and may result in poor densities, poor surface texture and poor ride ability. A minimum of 2” of HMA should be placed over any recycled product if the project is to lay over the winter. See Standard Specification 401.06 Weather and Seasonal Limitations for complete details on HMA placement dates.

13-7.3 Smoothness

To be used in future updates

13-8 SHOULDERS

As defined by AASHTO, the shoulder is the portion of the roadway adjacent with the traveled way for accommodation of stopped vehicles for emergency use, and for lateral support of the subbase and surface courses. Paved shoulders also promote surface drainage, improve overall safety, and lower maintenance costs. Shoulders should be durable, compatible with the adjacent mainline pavement, and strong enough to handle heavy truck encroachment and maintenance traffic.

13-8.1 Shoulder Features

Shoulder features such as width, break, cross-slope, and surface types are discussed in more detail in Volume One (National Standards) and Volume Two (State Standards) in the *MaineDOT Highway Design Guide.*

Shoulder widths vary according to the roadway functional classification and traffic volumes. The shoulder width is typically the distance from the edge of the travel lane to the shoulder break. Refer to Section 6-1.02 and to the design tables in Chapters 7 and 11 in Volume One, and to Sections B and C in Volume Two of the *MaineDOT Highway Design Guide* for guidelines on standard shoulder widths.

The shoulder break is the intersection of the shoulder slope and the embankment slope. The shoulder break typically begins at the edge of the shoulder pavement. Refer to Section 6-3.01 in Volume One, and to Section B in Volume Two of the *MaineDOT Highway Design Guide* for guidelines on shoulder breaks.

The cross-slope is the slope of the pavement towards the roadside. An increase in the shoulder cross-slope provides quicker drain off of water from the travel lanes. The cross-slope break should be at the edge of the travel way and the typical shoulder cross-slope used for design is 4%. Refer to Sections 6-1.01, 6-1.02, and to the design tables in Chapters 7 and 11 in Volume One, and to Section B in Volume Two of the *MaineDOT Highway Design Guide* for guidelines on travel lane and shoulder cross-slopes.

Shoulder surface types include paved and gravel surfaces. Refer to Section 6-1.02 and to the design tables in Chapters 7 and 11 in Volume One, and to Section C in Volume Two of the *MaineDOT Highway Design Guide* for guidelines on surface type selection.

13-8.2 Shoulder Design

Full-depth shoulders are HMA shoulders that have the same cross-sectional thickness and material types as the adjacent travel lane and are designed to have the same design life as the mainline. Full depth shoulders are often an economical alternative if shoulder widths are 4’ wide or less. From a constructability standpoint, these shoulders can be paved concurrently with the mainline, resulting in some potential savings and ease of construction. If shoulder widths are greater than 4’, the recommended thickness of HMA is 3”.
Partial-depth shoulders are HMA shoulders that have an HMA thickness less than the adjacent travel lane thickness. For new construction/reconstruction projects, the shoulder surface and intermediate HMA courses correspond to the travel lane HMA course thicknesses. To account for heavy truck wander, the full-depth section should be extended 24 inches into the shoulder.

Some shoulders are subjected to above normal traffic use, such as across from commercial entrances, the inside of curves, including ramps, in intersections, or opposite the leg of “T” intersections. To prevent the HMA on the shoulders from deteriorating prematurely, these locations should have full-depth shoulders even if the traffic information warrants partial-depth shoulders.

Full-depth shoulders should be used for intersections with safety widenings and should begin 20 feet before the Point of Curve (P.C.) and terminate 10 feet beyond the Point of Tangent (P.T.). When safety widenings are not provided, full-depth shoulders should be used 50 feet in advance of the P.C. and end 10 feet beyond the P.T.

Where right-turning traffic may illegally use the shoulder as a turn lane, full-depth shoulders should begin 165 feet in advance of the P.C.

Where large vehicles will have trouble negotiating curves and corners without encroaching onto the shoulders, the designer should use truck templates to determine whether full-depth shoulders should extend beyond the limits given above.

13-9 CONTRACT DOCUMENTS

Once the pavement design has been finalized and approved, a HMA pavement Special Provision (Section 403) must be generated for the contract documents. Since each project may have differing material and lift thickness requirements, a Special Provision must be generated for each project that addresses the project specific requirements for the Hot Mix Asphalt (HMA) used in the project. Special Provisions override the Standard Specifications, so it is extremely important that the 403 Special Provision accurately reflect the materials, quantities, and construction requirements of the project.

Once the pavement design has been approved and the HMA quantities have been determined, this information should be submitted to the Support Section to generate Special Provision-Section 403-HOT MIX ASPHALT. The Special Provision 403 request form outlines the type of materials to be utilized in the contract, the lift thicknesses of each type of material, quantity breakdown of each material between travel ways, widenings, ramps, shoulders, or other areas of material placement. An example of this request form is shown in Figure 13-5. This request form is located at \\Dot0dta1fsaug01\$com-cons\~O D G the New Millennium\403 Request Forms.

APPENDIX

FIGURE 13-1

STATE OF MAINE

FILE:

INTERDEPARTMENTAL MEMORANDUM

Date:

To: Ed Hanscom — Dept.: MDOT, Bureau of Planning

From: — Dept.:

Subject: **Request for Traffic Information** — Project Manager:

TOWN(S): — P.I.N. **0.00**

COUNTY:

DESCRIPTION:

(Select by making bold, circling, and/or entering 'other')

Existing Location	Relocation (Attach Sketch)	Turning Movement (Provide Locations under Comments)	Other:

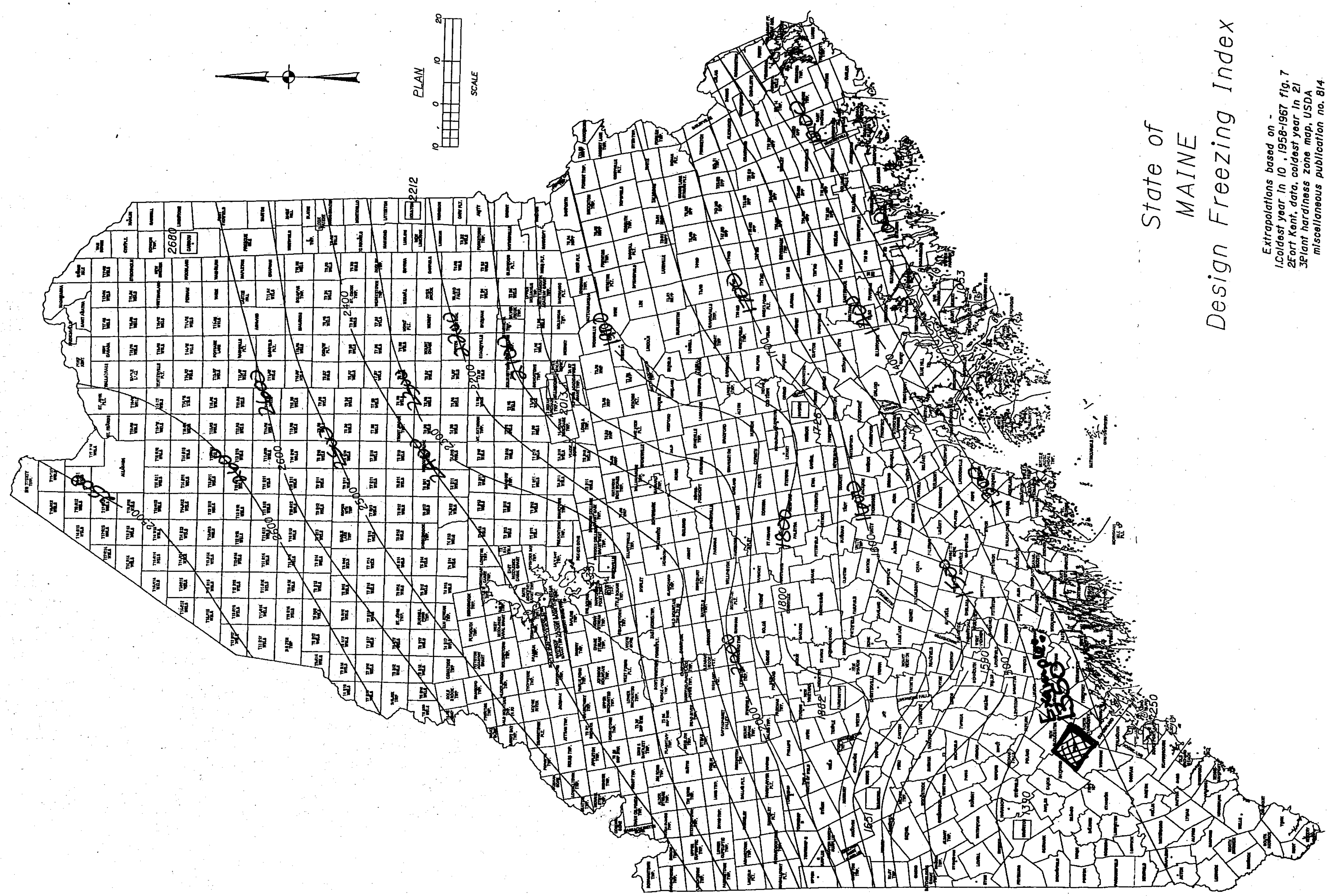
	Sec. 1	Sec. 2	Sec. 3	Sec. 4	Sec. 5
Description of Sections					
Current AADT (Year)					
Current ____ AADT					
Future ____ AADT					
Future ____ AADT					
DHV - % of AADT	0%	0%	0%	0%	0%
Design Hourly Volume					
% Heavy Trucks (AADT)	0%	0%	0%	0%	0%
% Heavy Trucks (DHV)	0%	0%	0%	0%	0%
Direct.Dist. (DHV)	0%	0%	0%	0%	0%
18-KIP Equivalent P 2.0					
18-KIP Equivalent P 2.5					

Notes or Remarks:

PLEASE PROVIDE A MAP OF THE PROJECT AREA, AND
THE CURRENT AND FUTURE YEARS FOR WHICH YOU WANT THE AADT CALCULATED

Comments:

FIGURE 13-2



State of
MAINE
Design Freezing Index
Extrapolations based on -
1.Coldest year in 10 , 1958-1967 fig.7
2Fort Kent, data, coldest year in 21
3Plant hardiness zone map, USDA
miscellaneous publication no. 814
PLAN
SCALE

FIGURE 13-3

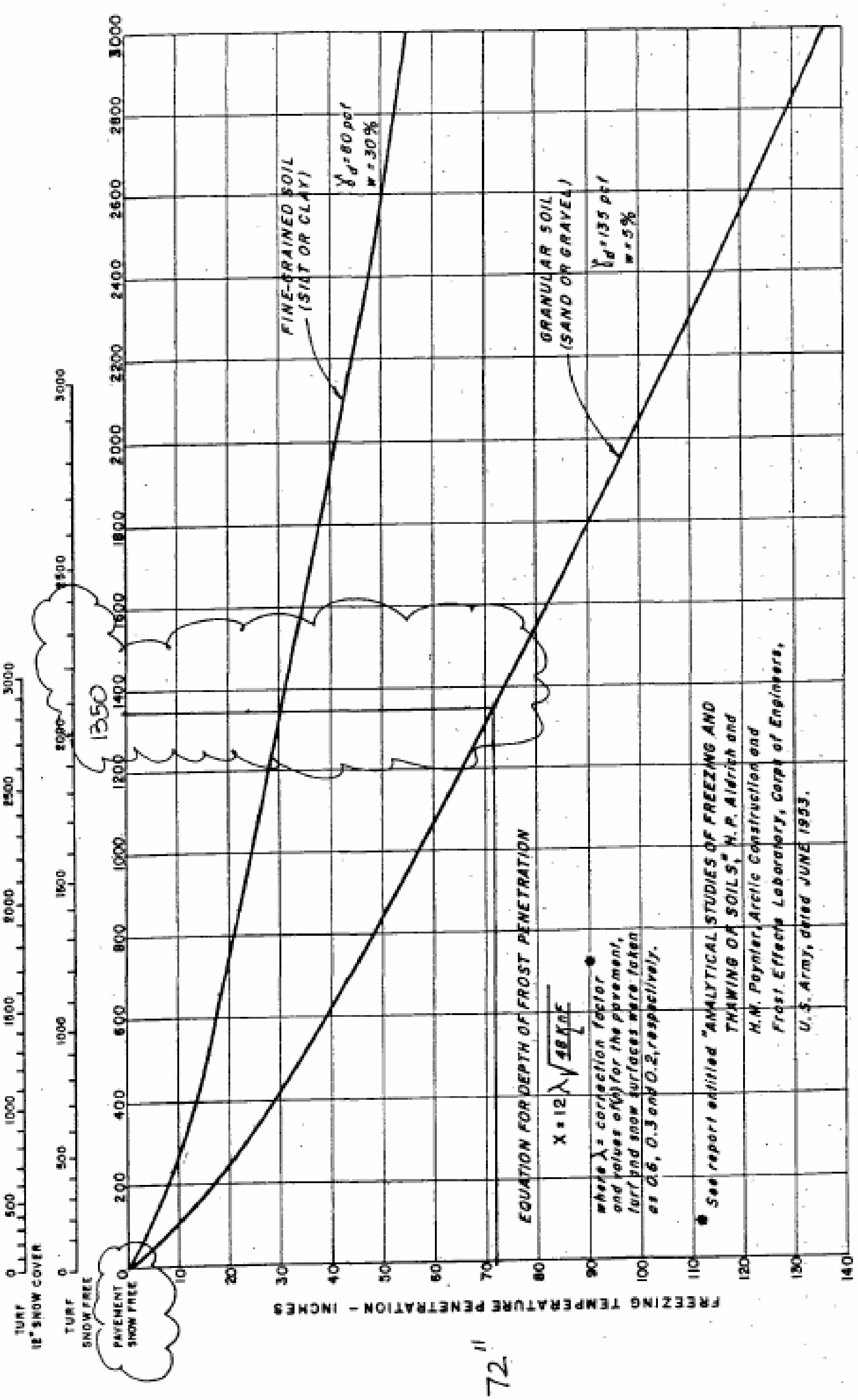
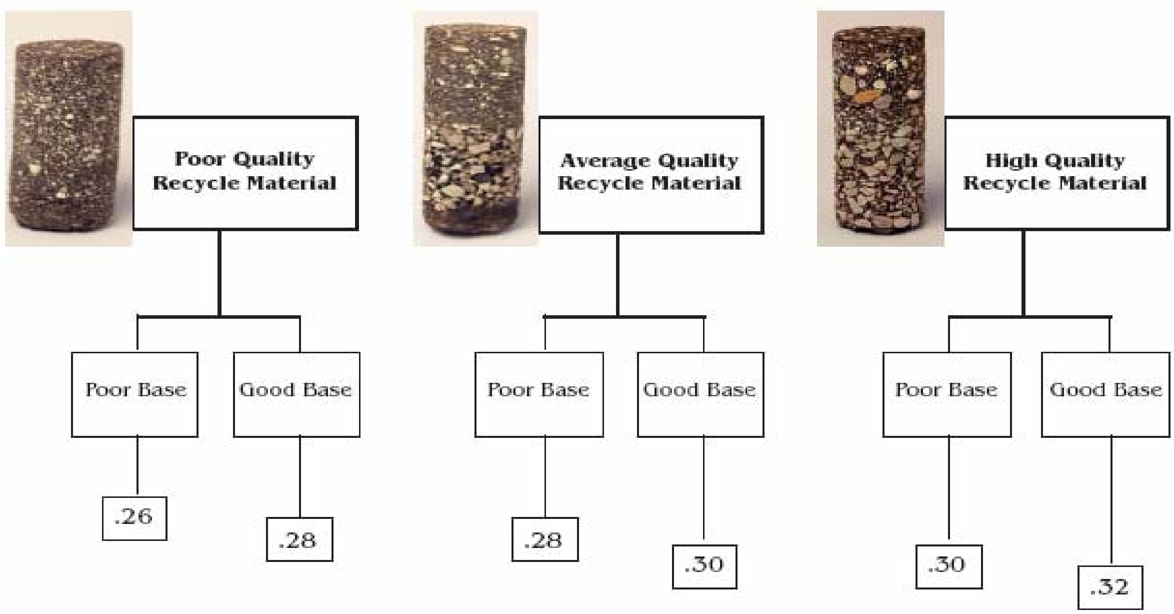


Figure 13-3 RELATIONSHIP BETWEEN FREEZING INDEX AND FREEZING TEMPERATURE PENETRATION FOR VARIOUS SURFACE CONDITIONS FOR GRANULAR AND FINE-GRAINED SOILS

FIGURE 13-4

LAYER COEFFICIENTS FOR RECYCLED MATERIAL



These numbers represent the range of value used by the Department for recycled materials treated with a stabilizer additive. The designer must use some engineering judgment to determine the most appropriate number for the given project conditions. For the purposes of this table, poor base is defined as material not meeting specification 703-06 or saturated material.

Table 13-2

Structural Coefficient Guidance

The structural coefficients for these recycled treatments vary depending on the existing conditions of the roadway. The designer must use engineering judgment to determine the proper structural coefficient to use for a given application, within the assigned range. The following three things need to be considered:

1) Type of mix being recycled. If the existing HMA layers consist of designed mixes with good quality aggregates then a higher structural coefficient can be used. Conversely, if the existing HMA layer consists primarily of sand mix (Maintenance Mulch) then a lower number should be considered.

2) Underlying Material. If the underlying material is new, or the existing material meets current Department standards, then a higher structural number can be assumed. If the underlying material is of a lower quality, then a lower structural number should be considered.

3) Drainage characteristics: If you have a well drained pavement structure, you can assume a higher structural number (i.e. under drain or adequate depth ditches). If you do not have adequate drainage, or there is a high probability of saturated subgrade soils being present, a lower number should be considered.

FIGURE 13-5

To:	Brian Luce; Bituminous Special Provisions (Brian.Luce@Maine.Gov)
Note:	Please include Typical Sections for Bituminous Items.
From:	
Bureau, Office or Division:	
Subject:	Pavement Design Information, (Special Provision, **Sec. 403**) for the following project:

Project #:__________
Town(s)/City(s)_____
Pin #:_________________ Route #(s) __________________Project Level _____
Traffic Data Level: 80-kN ESALs Over 20 Years _____ (18 kip @ 2.5 x 365 x 20 yr = ESAL's)
Approx. Mg or Tonnage Quantities for Item - 403.208 12.5mm Surface Mix
Approx. Mg or Tonnage Quantities for Item - 403.207 19.0mm Base Mix
Approx. Mg or Tonnage Quantities for Item - 403.211 9.5mm Shim and Leveling Mix

Mainline Overlay	**Shoulders**	**Approach Roads**	**Shim (Leveling mix)**
Paved Surface Course	**Paved Surface Course:**	**Paved Surface Course:**	YES NO
Depth: _____	Depth: _____	Depth: _____	Variable Depth (__)
Type Mix :_____	Type Mix: _____	Type Mix: _____	½" minimum (__)
Quantity: _____	Quantity:_____	Quantity:_____	Other_____
	Overlay (__)orGravel (__)		
Paved Base Course:	**Paved Base Course:**	**Paved Base Course:**	
Depth: _____	Depth: _____	Depth: _____	
Type Mix: _____	Type Mix: _____	Type Mix: _____	
Quantity :_____	Quantity:_____	Quantity:_____	

Full Construction	**Recycled Pavements** (C.I.P; R.A.P)	**Paved Shoulders**
Paved Surface Course:	**Paved Surface Course:**	**Paved Surface Course:**
Depth: _____	Depth: _____	Depth: _____
Type Mix: _____	Type Mix: _____	Type Mix: _____
Quantity:_____	Quantity:_____	Quantity:_____
Paved Base Course:	**Paved Base Course:**	**Paved Base Course:**
Depth: _____	Depth: _____	Depth: _____
Type Mix: _____	Type Mix: _____	TypeMix:
Quantity:_____	Quantity:_____	Quantity:_____

Please check **Y** or **N** if the following apply: **Is this project to take more than one construction season? YES (__)**
NO (__)

	YES	NO	DEPTH
Sidewalks	(__)	(__)	_____
Drives	(__)	(__)	_____
Islands	(__)	(__)	_____
Miscellaneous	(__)	(__)	_____
Quantity:	_____		

Will this project require the use of note # 20
Open centerline joint on ¾ inch (20mm) surface course YES (__)
NO (__)

Will this project require the use of note # 20
Open centerline joint on shim. YES (__)
NO (__)

Is this Project a Ride Quality Candidate ? YES (__) NO (__)

Comments:__________

CHAPTER FOURTEEN

ESTIMATING QUANTITIES

Volume I

- Highway Design Guide –

National Standards

December 2004

Chapter Fourteen

TABLE OF CONTENTS

Page

Chapter Fourteen

ESTIMATING QUANTITIES

14-1 GENERAL

14-1.01 Objective

One of the most important responsibilities of the designer is to compile an accurate estimate of the project construction quantities. This information leads directly to the Engineer's Estimate, which consists of two elements: 1) computed quantities of work, and 2) the estimated unit bid prices expected. An accurate estimate of quantities is critical to prospective contractors interested in submitting a bid on the project.

Chapter Fourteen presents detailed information on estimating quantities for highway construction projects. The designer should recognize that most information available from the Department is public information and should not be withheld from anyone making a reasonable request. However, the Engineer's Estimate must remain *CONFIDENTIAL* as designated by Maine Statute. All personnel are advised not to reveal the total estimated cost of projects with anyone outside the Department before or after bid opening.

14-1.02 Estimates for Pay Items

Section 14-2 presents detailed information for estimating quantities for construction pay items. Section 14-3 presents rounding and adjustment factors specifically for calculating the quantities for the pay items. The following also applies to estimating quantities:

1. All items should be cross checked against the *Standard Specifications* and Supplemental Specifications to ensure that the appropriate pay items, methods of measurement and bases of payment are used.

2. In preparing the preliminary estimate computations, a separate sheet should be included for each item used on the project, although the quantity may be computed in another section of the estimate with some related item. In this case, a cross reference to the location of the computations is needed.

3. The quantity of any item shown on the estimate form should check exactly with the figure shown on the computation sheet. Any rounding of the raw estimated figures should be indicated on the computation sheets. *See Section - 14-1.03 #5 below.*

4. Some projects will require two or more estimates, representing the work done under various financing arrangements. Thus, work performed for a town (e.g., sewers, sidewalks) under the contract and according to a "Town Agreement" will be on a separate estimate. Similarly, separate estimates will be prepared for "Non-Federal" work and for work on each highway system on the project. Specific instructions regarding the several estimates required will be obtained from the Group Leader. A combined estimate should also be made with total quantities for the project when two or more estimates are required.

5. Each item within the estimate computations should have a separate page. Items which require more than one page should have a one page summary listing the sheet totals and quantity totals for the appropriate item. This summary page should index the other pages for the item.

14-1.03 Engineer's Estimate Form

The designer should follow these procedures in preparing the Engineer's Estimate Form (see Appendix 14A):

1. Use only the standard ESTIMATOR estimate form. The estimate is entered into the computer; therefore, the information must be provided in a consistent manner.

2. Complete the top of the Estimate Form as completely as possible, including route and highway numbers, towns, county, estimator, PIN and Federal project number.

3. Be sure the project number is correct. This includes not only the numerical digits but also the prefix letter, if needed.

4. Make sure that the official project length agrees with the plan title sheet.

5. Be realistic when entering quantities and prices. Use the "Rules for Rounding" in Section 14-3 for estimated quantities. Avoid amounts in the "cents" column, if possible.

6. Small quantities of rock excavation may be a separate bid item or paid at six times the earth excavation price and included as a non-bid computer item.

7. For lump-sum items used on several estimates, prorate the share for each in accordance with monetary value. For example, A Field Offices≅ should be prorated in accordance with the total cost, whereas ATesting Facilities, Bituminous Mixes≅ should be prorated in accordance with the value of the bituminous items used.

8. Be sure quantity and price extensions are mathematical. For example, L.S. x $25,000 does not equal $25,000; show as 1 x $25,000. Also, 33 percent x 3,000 does not equal 990; show as 0.33 x 3,000 = 990. Show to two decimals only.

9. Be sure items are listed in numerical order by item number.

10. Be sure the **writing** is **legible** and **dark** enough so that the estimate can be photocopied.

11. The following will apply to lump-sum items:

    a) When a lump-sum item has an underlying quantity that can be computed, enter the underlying quantity and the unit price to extend out to the lump-sum price. Example:

Item No.	Description	Unit	Quantity	Unit Price	Amount
202.19	REMOVING EXISTING BRIDGE	LS/CY	200	$ 200	$ 40,000
502.31	STRUC CONC APPROACH SLAB	LS/CY	21	$ 280	$ 5,880
504.71	STRUCTURAL STEEL ERECTION	LS/LB	200,000	$ 0.10	$ 20,000

    b. If a lump-sum item's underlying quantity cannot be estimated or consists of several items with a known quantity (such as removal of a bridge with 100 tons of structural steel and 160 yards of concrete), then enter a quantity of 1 with the unit price equal to the lump-sum price. Example:

Item No.	Description	Unit	Quantity	Unit Price	Amount
202.19	REMOVING EXISTING BRIDGE	LS/CY	1	$50,000	$ 50,000

c. When a lump-sum item does not have an underlying quantity, the quantity should be entered as 1 with the unit price equal to the lump-sum price. Example:

Item No.	Description	Unit	Quantity	Unit Price	Amount
659.10	MOBILIZATION	LS	1	$30,000	$ 30,000

d. When a lump-sum item is used more than once on a project, repeat the item number and append a supplemental description. Example:

Item No.	Description	Unit	Quantity	Unit Price	Amount
202.08	REMOVE BUILDING <u>#1</u>	LS	1	$ 500	$ 500
202.08	REMOVE BUILDING <u>#2</u>	LS	1	$ 2,000	$ 2,000
506.18	CONTAIN & POLLUT CONTROL <u>BR#1</u>	LS/LB	100,000	$ 0.10	$ 10,000
506.18	CONTAIN & POLLUT CONTROL <u>BR#2</u>	LS/LB	100,000	$ 0.10	$ 10,000

14-2 PROCEDURES

This Section presents the procedures the designer should follow for estimating construction quantities for pay items. The designer should also note that many references to plan notations will be found throughout this section. In general, notations should not be duplicated; for example, clearing notes (Station to Station and side) should be placed only on the sheet where the particular clearing area begins. Notations for the item and location of work on the plans should be the same as in the estimate to facilitate cross-reference. Unusual notations should be presented in the General Notes not on the plans.

201.11 Clearing - Acres

The designer should follow these procedures:

1. Clearing shall be estimated for all wooded areas bounded by clearing lines.

2. Clearing lines may be defined as a line showing the break between a wooded area and a clearing or as a line showing the limit of a wooded area to be cleared.

3. Clearing areas shall be designated during the final field inspection.

4. Outside clearing lines shall be placed parallel to and 10 feet (15 feet for freeways in non-guardrail fills and low cut slopes) from the slope lines. Clearing lines may extend beyond the R/W line with easements.

5. Thin windrows or unprotected clumps of trees created as a result of standard clearing designations should be reviewed for inclusion in the clearing areas.

6. All clearing lines, except those defined by a general note to be parallel to the slope lines, shall be clearly shown and labeled on the plans.

7. Clearing areas shall be noted on the plans with the beginning and end stations and side shown. Beginning and end stations should be the actual point of beginning or ending at right angles to centerline regardless of skew. An exception to this may be taken on some projects when the clearing is spotty and/or overlapping, if full clearing lines and some type of delineation like hatching or shading is used.

8. When no item for clearing is included in the contract, any necessary clearing is paid under Subsection 109.3, unless otherwise noted in the General Notes.

9. The estimated quantity of clearing shall be determined by any of the following methods:

   a. average width and length,
   b. planimeter, and
   c. computer program.

10. When clearing is less than 0.5 acres, it will be considered incidental to the contract and so designated in the General Notes.

201.12 Selective Clearing and Thinning - Acres

The designer should follow these procedures:

1. Selective clearing and thinning may be designated for the following areas:

   a. the area between the clearing lines and the R/W lines,

   b. the median area between clearing lines on divided highways,

   c. areas beyond clearing lines of ramp gores, and

   d. special areas requested by the Landscape Architect, including areas outside the R/W, where landscaping work easements have been obtained.

2. Any designation of selective clearing and thinning areas must have the approval of the Project Manager.

3. When selective clearing and thinning is used, the width of the area shall be limited to 100 feet unless otherwise requested by the Landscape Architect and approved by the Project Manager.

4. All selective clearing and thinning lines, except those defined by a general note to be parallel to the clearing lines, shall be clearly shown and labeled on the plans.

5. Selective clearing and thinning areas shall be noted on the plans with the beginning and end stations and side shown. Beginning and end stations should be the actual point of beginning or ending at right angles to the centerline regardless of skew. An exception to this may be taken on some projects when the selective clearing is spotty and/or

overlapping, if full selective clearing lines and some type of delineation like hatching or shading is used.

6. The estimated quantity of selective clearing and thinning shall be determined by any of the following methods:

   a. average width and length,
   b. planimeter,
   c. computer program.

7. Certain areas outside the R/W lines, such as areas adjacent to muck storage areas, may be designated for clean-up. If so, they shall be noted on the plans, and the work required will be paid for under Item No.629.05, Hand Labor Straight Time, Item No. 631.18, Chain Saw Rental (including operator) and other applicable equipment rental items. Selective clearing and thinning should not be used for this purpose. NOTE: This work should be noted on the plans as Equipment Rental, or the work will be Blue Book Rates.

201.23 Removing Single Tree Top Only - Each

Trees less than 1-foot in diameter will not be considered as trees under this item. Trees in clearing areas will be paid for as clearing.

201.24 Removing Stump - Each

The designer should follow these procedures:

1. Refer to Subsection 201.09 of the *Standard Specifications* for the method of measurement for multiple trunk trees. Stumps are considered to be such if less than 5 feet in height.

2. A tree which will be removed entirely will be estimated under both the item for "Removing Single Tree Top Only" and "Removing Stump".

3. Trees and stumps to be removed shall be marked "Remove" on the plans. Details, such as whether or not the stump is also to be removed, are to be omitted from this note because this information is given in the table in No. 4.

4. Tree and stump removal are to be listed in tabular form in the profile portion of the plans with stumps, if any, listed opposite the corresponding tree.

STA.	OFFSET	TREE	STUMP
520 + 10	51' Lt.	20" Oak	20"
521 + 80	40' Lt.		12"
521 + 90	35' Lt.	14" Pine	*

* Indicates that stump removal not required.

5. All stumps in grubbing and excavation areas, which are located outside of designated clearing areas and have resulted from a tree removal on the project must be estimated for removal under the stump removal item. Other stumps should be removed, as necessary, to allow the project to be satisfactorily completed.

6. Removal of stumps in areas where disruption to the surrounding ground is not desired may be done under and paid for by Item 631.20, Stump Chipper Rental (incl. operator). The Project Manager shall determine when to use Stump Chipper Rental instead of Stump Removal.

7. All bushes, shrubs and non-pay trees outside clearing or selective clearing and thinning areas should be noted to be removed.

202.0801 Removal of Building No. 1 Lump Sum

202.0802 Removal of Building No. 2 Lump Sum

202..... Removal of Building No. . . Lump Sum

The designer should follow these procedures:

1. The disposition of all private property (buildings, gas pumps, underground tanks, appurtenances, etc.) shall be determined by the Chief of R/W Operations and shall be noted on the plans.

2. In general, a group of buildings under one ownership, such as a house, barn and garage, shall be estimated as separate bid items, one for each building. This procedure will allow the property owner the option of removing one building only for salvage value and leaving the other buildings without interrupting the Contractor's bid.

3. Each building to be removed shall be clearly noted adjacent to the subject building as to station, side, item number and description.

Example: Sta. 24 + 10 Lt., Item No. 202.0801, Removal of Building No. 1, 1½ story house.

4. It should be noted that the standard pay item for removal of buildings includes only that portion of the building above the foundation and does not include filling the foundation cavity or removal of the foundation, when required. The filling, or removal, of foundations, therefore, should be estimated under normal earthwork items, unless this work has been specifically included in any special provision written concerning the removal of a particular building.

5. Building removal items, reserve limit lines and dates of availability should be reviewed with the R/W Division just prior to advertising the project.

202.11 Removing Portland Cement Concrete Pavement - Square Yard

The amount of concrete pavement that shall be estimated to be removed shall be that amount noted on the plans and cross sections. In general, concrete pavement shall be removed when the depth from finished grade to the top of the concrete pavement is 3 feet or less.

202.12 Removing Existing Structural Concrete - Cubic Yard

The designer should follow these procedures:

1. This item is normally used in bridge work but may be used when a highway designer wishes to remove portions of foundations, retaining walls, etc. The estimated quantity should be the cubic yards of structural concrete to be removed.

2. The designer also has the option to use rock excavation (structural or common) either as a bid item or non-bid item to get this type of work done, but he is cautioned that he must note how any remaining portions of the structure should be left and that there will be no separate payment for the necessary trimming work.

202.13 Removing Existing Railings (Retained by Department) – Linear Foot

202.14 Removing Existing Railings (Property of Contractor) – Linear Foot

These items are normally used in bridge work but may be used by the highway designer when he wishes to salvage hand rails, ornamental rails, special protective rails, etc., and/or when the removal and disposal of an existing rail will be a costly operation for the Contractor. The estimated quantity is the number of linear feet of rail from outside to outside of end posts measured along the grade and line of the rail.

202.15 Removing Manhole or Catch Basin - Each

This work shall consist of the removing and demolishing of existing catch basins, manholes, or end walls necessary for successful project completion. These items shall be clearly noted to be removed on the plans.

202.202 Removing Pavement Surface - Square Yard

The following will apply:

1. This item should be used on partial-depth, bituminous pavement grinding only.

2. Use common excavation for removing bituminous pavement over portland cement concrete pavement.

202.203 Pavement Butt Joints - Square Yard

203.20 Common Excavation - Cubic Yard

Sum of Common Excavation Quantity

The amount of "Common Excavation" to be estimated for a project shall be the cumulative summary of the following items that shall be considered on all projects:

1. ***Common Excavation from Cross Sections***. This item shall consist of all earth removal shown on the cross sections including grubbing and muck excavation. This quantity will

be determined by use of the computer or planimeter. Volumes shall be computed by the average end area method or by other methods generally recognized as conforming to good engineering practice.

2. ***Drives***. This item shall consist of all common excavation required to construct the drives as shown on the cross sections. This quantity shall generally be determined by the use of width, length and depth measurements.

3. ***Removing Existing Roadways***. If not otherwise accomplished through the use of equipment rental items, this work shall consist of the earth excavation required to remove old pavement from designated areas outside the embankment area to prepare these areas for loaming and seeding. Obliteration of old roadways is to be noted on the plans. The material so removed will be considered available for the embankment construction process. Removing old concrete pavement may be done as common excavation but, normally, it will be done under Item 202.11 Removing Portland Cement Concrete pavement.

   Removing existing bituminous pavement within or outside embankment areas must be salvaged, and the quantity will be estimated in cubic yards and paid for as Common Excavation.

4. *Grubbing in Fill Sections*. When the depth of an embankment (measured vertically below subgrade) is 5 feet or less, the area upon which the embankment will be placed shall be grubbed to remove all trees and stumps less than 12 inches, roots, bushes, grass, turf or other objectionable material. The outside grubbing limit shall be established as follows:

   a. When the depth of embankment below subgrade is 5 feet or less but greater than 2 feet, the outside grubbing limit shall be constant. This constant offset shall be determined by intersecting a 1:1 slope from the shoulder edge with the old ground based upon a normal roadway section that measures 5 feet from old ground to subgrade.

   b. When the depth of embankment is less than 2 feet, the outside grubbing limit shall be the subgrade slope/side slope intercept unless the distance from the subgrade slope/side slope intercept to the beginning of the ditch excavation is less than 10 feet, and greater than 5 feet. If this width is less than 10 feet, grubbing shall extend to the beginning of the excavation.

In areas where the vertical distance from subgrade to old ground is irregular and exceeds 5 feet for short distances, grubbing shall be continuous to avoid small ungrubbed areas and sharp breaks in the grubbing lines.

Grubbing in fill areas shall be shown on the cross sections and the estimated quantity indicated as a station-to-station quantity in cubic yards (G 27 CY).

When grubbing is required beyond the toe and/or top of slopes to remove objects that would be hazardous if struck by out-of-control vehicles, it shall be estimated and paid for under the applicable equipment rental which shall be included in the Schedule of Items, as so noted in the General Notes.

If specific information concerning the depth of grubbing is not available from soils reports or other sources, grubbing depths for projects located in maintenance regions 4 and 5 (Aroostook, Hancock, Penobscot, Piscataquis and Washington Counties) shall be 15 inches for clearing areas and 9 inches for other areas. Grubbing depths for projects located elsewhere shall be 12 inches for clearing areas and 6 inches for other areas. This is summarized below:

Maintenance Region	Woods	Other Areas
4 & 5	15”	9”
All Others	12”	6”

5. *Benching*. When fills are placed on hillsides or existing embankments with slopes steeper than 2:1, benching must be indicated on the cross sections. Generally, benches should be a minimum of 10 feet in width and be designed so that a bulldozer can cut them in a continuous manner from one station to another. The payment of benching shall be incidental to item 203.20, Common Excavation.

6. *Salvaged Topsoil*. This item shall consist of that amount of excavation required in embankment areas to salvage topsoil from embankment areas.

7. *Overlays*. On overlay projects when a culvert pipe is replaced, the quantity of excavation in the trench down to a theoretical subgrade line is paid for as Common Excavation.

8. *Waste Storage*. Waste storage will be estimated and used only on borrow projects, and the area must be shown on the cross sections as detailed in the Standard Detail Book.
In culvert locations, waste storage must not be placed within 5 feet of the outside diameter of the proposed culverts.

Waste storage areas must be shown on the cross sections and the estimated quantity indicated as a station-to-station quantity in cubic yards (WS 27 CY).

Excavation for Slope Blanket - cubic yard

For non-bid item, use number 203.2009 for computer input. Excavation for slope blanket shall be estimated for those areas where there is a possibility of unstable backslopes. These areas will generally be specified in the Soils Report. The total bid quantity of excavation for slope blanket shall be shown in the Engineer's Estimate as a non-bid item and the unit price established as twice the unit price of common excavation. The notation of excavation for slope blanket should be similar to the following:

Sta. 25+30 to Sta. 27+20 Lt
Excavation for Slope Blanket
Aggregate Subbase for Slope Blanket
Estimated Quantity = 130 CY
Depth: 18”

Muck Excavation - Cubic Yard

The designer should follow these procedures:

1. The amount of muck excavation to be estimated shall be the entire amount of muck shown on the cross sections.

2. The muck excavation limit lines and the embankment areas designated for the disposal of waste materials shall be determined as shown in Standard Detail Book page 203(01).

3. Plot the depth and horizontal dimensions of muck excavation on the cross section and note the station-to-station volume in cubic yards (example M 369 CY).

4. Plot the depth of muck on the profile and note the station-to-station limits on the cross section.

5. In disposing of the muck, every effort shall be made to provide muck storage within the highway embankments adjacent to the excavation area.

6. The width will be determined by a 1:1 slope from the edge of the shoulder to the bottom of the muck excavation or to the toe of fill slope, whichever produces the smaller width

203.21 Rock Excavation - Cubic Yard

The designer should follow these procedures:

1. The amount of "Rock Excavation" estimated for a project shall be the cumulative sum of the applicable items as follows:

    a. Rock Excavation from Cross Sections: This shall consist of all rock excavation shown on the cross sections and as detailed in the typical sections for removal. It should be noted that rock excavation will be paid to the neat lines shown and that no over breakage is to be estimated.

    b. Boulders: This shall consist of all boulders (exposed or subsurface) requiring removal which have a volume of 2 cubic yards or more. If the quantity of boulders is extensive, an attempt should be made to determine the amount involved, and consider bidding the excavation unclassified.

2. When the volume of rock excavation is less than 1000 yards and is also less than 5 percent of the common excavation volume, the quantity will be shown as a non-bid item and the unit price established as 6 times the common excavation unit price.

3. Pay to the 4:1 backslope.

4. The estimated quantity of rock excavation shall be shown on the cross sections as a station-to-station quantity in cubic yards (Example: R 59 CY).

203.211 Presplitting Rock – Linear Feet

Place holes 18 inches apart along the plane of fracture to the bottom of the proposed cut.

203.22 Unclassified Excavation - Cubic Yard

The designer should follow these procedures:

1. On certain projects where the excavation consists of a high percentage of boulders and/or soft ledge, unclassified excavation may be used in lieu of classifying the excavation.

2. In order that the Contractor can intelligently bid on the project and an accurate estimate of the total excavation can be made, rock excavation shall be shown on the cross sections as outlined under Subsection 203.21 of this Chapter.

3. Because the price per cubic yard of unclassified excavation will be higher than that for common excavation, extra care should be used in estimating this item.

203.24 Common Borrow - Cubic Yard

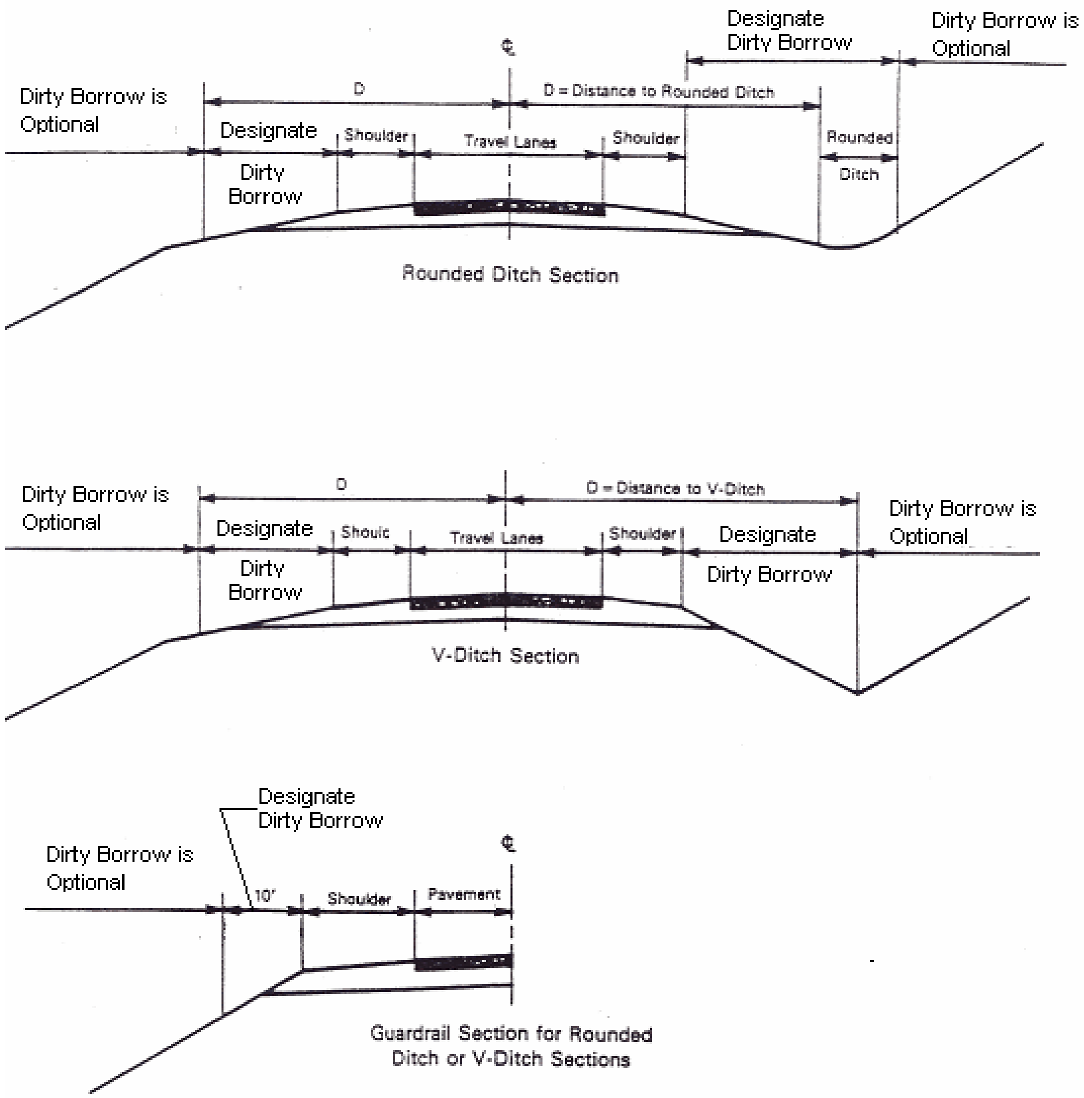
The designer should follow these procedures:

1. This item shall be used to provide fill material as necessary to complete the embankments on a project.

2. To determine the estimated quantity of common borrow, a summary of the project earthwork should be prepared as outlined on the standard form for Computation of Preliminary Quantities, Appendix 2D.

203.24 Dirty Borrow - Cubic Yard

The amount of Dirty Borrow to be estimated for a project shall be that amount required under Seeding Method #2 and areas specified on the Plans and/or Cross Sections measured in place. The depth of Dirty Borrow shall be estimated at 2” unless specified differently. See Figure 14-1.



POLICY ON LOAMING HIGHWAY SLOPES

Figure 14-1

203.25 Granular Borrow - Cubic Yard

The amount of granular borrow to be estimated for a project shall be the sum of the applicable possible usages of granular borrow as described:

1. ***Granular borrow to replace muck***. In general, all removed muck shall be replaced with granular borrow. Rock excavation should be used to replace muck only when the available quantities of embankment materials would require the wasting of rock excavation unless it were used to replace muck or when the estimated cost of granular borrow would appear to be excessive. Whenever rock excavation will be used, a 2-foot minimum depth initial layer of granular borrow should be specified.

2. ***Granular borrow for use in low, wet areas***. Granular borrow shall generally be estimated for the bottom (2-foot) of embankments in low, wet areas. The width of this initial layer should be limited to that area inside the waste area storage lines. The locations and depths required for this usage can generally be determined from the soils report and/or the field inspection. In addition, when grubbing or muck excavation is replaced with granular borrow, the granular borrow shall be brought to a minimum of 1-foot above water level.

3. ***Granular borrow for embankment construction near bridges and box culverts*.** The limits of the granular borrow embankments for this usage will be determined by the Bridge Design Division and shall be appropriately defined on the highway plans.

4. ***Granular borrow for maintenance of traffic*.** The specifications for most projects that are required to carry traffic during construction will generally require a minimum roadway width of 20 feet two lanes of traffic. In many instances, this specification will cause the widening of the existing roadway or the topping of partially completed embankments to provide the required width. In both instances granular borrow will be used to accomplish the desired results.

   On overlay projects, include this item as Truck Measure.

5. ***Granular borrow for culvert bedding*.** If granular borrow is used for this purpose, a general note should be made on the plan stating that payment will be made as granular borrow and that the material meets the requirements of granular borrow for underwater backfill.

6. ***Granular borrow for general embankment construction.*** The following applies:

   a. On some projects a certain percentage of the borrow requirements will be estimated as granular borrow to aid in the construction of embankments by allowing alternate layers of granular material and excavated material to be placed.

   b. On some projects when a large supply of granular borrow is readily available, the entire borrow requirements may be estimated as granular borrow. If this decision is made, the estimating procedure described under Item 203.24 Common Borrow should be followed.

   c. On some projects, if required by the nature of common excavation or by seasonal variations, granular borrow should be blended with excavated material in the embankments to facilitate construction and maintenance of traffic.

A summary of the granular borrow requirements shall be made, and this summary shall be shown on the earthwork summary.

203.26 Gravel Borrow - Cubic Yard

203.261 Gravel Borrow (I.P.M.) - Cubic Yard

Gravel borrow is most frequently used for construction near bridges and box culverts and is now often being replaced by granular borrow. The limits of the gravel borrow and the method of measurement will normally be determined by the Bridge Design Division and shall be appropriately defined on the highway plan.

203.27 Rock Borrow - Cubic Yard

The designer should follow these procedures:

1. Whenever the amount of rock fill, rock for slope protection, or other rock uses exceeds the amount of available rock excavation, rock borrow shall be estimated.

2. The required locations of rock fill shall be shown and noted on the profile and cross sections, and rock for slope protection shall be noted on the plans and cross sections and shown on the typical sections and/or cross sections.

3. Care should be taken to ensure that the required amount of rock borrow estimated in place is shrunk 25 percent prior to being placed on the Engineer's Estimate as rock borrow.

203.29 Selected Granular Material - Cubic Yard

This item is an open-graded granular material which is normally used only for Interstate subbase construction. The quantity for the estimate and payment is computed in place measured from the typical sections and/or height, width and length measurements where applicable. Use of this item will be determined by the Project Manager at the time that the typical sections are being developed.

203.30 Lightweight Borrow - Cubic Yard

203.31 Lightweight Borrow - Ton

The designer should follow these procedures:

1. This item is a lightweight (less than 65± lbs per cubic foot) expanded shale or slate fill material which may be used where it is necessary to decrease soil weight to be able to construct a fill to the planned grades.

2. Other methods to accomplish similar results should also be considered:

   a. toe fill counterweights,
   b. staged embankment construction and time,
   c. sand drains and time,
   d. stabilization geotextiles
   e. plastic lightweight embankment,
   f. excavation and replacement of sensitive material, and
   g. various combinations of the above as recommended by the Soils Engineer.

3. Lightweight borrow is measured in cubic yards completed in place. The dimensions used for measurements will be those shown on the plans as normally provided by the Soils Section.

204.41 Rehabilitation of Existing Shoulder, Plan Quantity - Square Yard

The amount of shoulder rehabilitation shall be that amount as measured from the plans in square yards. This item should be used on resurfacing type projects with gravel shoulders only.

205.51 Widening of Existing Shoulder - Square Yard

206. Structural Earth Excavation Drainage and Minor Structures - Cubic Yard

Structural earth excavation shall be estimated as required for all drainage systems on a project. It shall be estimated for culverts, underdrains and catch basins. Payment is incidental to the structure. The total quantity should be listed in the general notes. Ditches at inlets and outlets of culverts, special ditches and channel excavation will be paid under Item 203.20.

Because of the desire for uniformity between projects the following guides must be used by all designers in estimating structural earth excavation drainage:

1. ***Underdrain***. Structural earth excavation drainage for underdrain shall be estimated for the widths specified in the standard details and for a length and depth as shown on the plans. When underdrains are connected to a catch basin, structural earth excavation drainage shall be estimated to within 18 inches of the outside wall of the catch basin.

2. ***Culverts.*** Culverts are normally installed as positive projecting conduits. The quantity of structural excavation estimated shall be based upon the length, width and depth of excavation (include only material not otherwise removed) necessary to place the pipe to the proposed line and grade and width of 30 inches plus the outside diameter of the pipe. The wall thickness of rigid pipes should be used in computing the quantity of structural excavation. Wall thickness equals in inches:

   $$\frac{\textit{size of pipe in inches}}{12}+1$$

   When culverts will be installed as zero projecting conduits or by imperfect (induced) trench method, the quantity of structural earth excavation estimated shall be the volume determined from the special details shown on the plans or cross sections.

   When culverts are connected to catch basins, structural earth excavation drainage shall be estimated to within 18 inches of the outside wall of the catch basin.

3. ***Catch Basins***. In excavation areas the quantity of "structural earth excavation drainage" to be estimated is that volume below subgrade that must be removed to vertical planes (circular or flat) 18 inches outside the neat lines of the base as shown on the plans.

If the catch basin has a culvert connected to it that will be installed as a zero projecting conduit, the depth of structural earth excavation drainage estimated shall be based upon a depth from the top of the trench for the culvert to the bottom of the catch basin base.

In fills, structural excavation for underdrain, catch basins, manholes and interconnecting pipes within a closed drainage system should be estimated from the subgrade elevation.

206.061 Structural Earth Excavation - Drainage and Minor Structures, Below Grade – Cubic Yard

This item is structural excavation which has been limited to below a plane parallel with and 12 inches below the bottom of drainage structures. Computation of the quantity is the same as for Standard Structural Excavation within the limits set in the 206 Items. Add 50 CY for undetermined locations.

206.07 Structural Rock Excavation - Drainage and Minor Structures - Cubic Yard

The designer should follow these procedures:

1. When rock is encountered, structural rock excavation-drainage shall be estimated using the same criteria and the same horizontal excavation limits as in structural earth excavation. The depth for measurement will be the actual depth required.

2. Estimate 12 inches below the bottom of the pipe for culvert pipes and Underdrain Types "B" and "C".

3. Estimate 6 inches below the bottom of catch basins and manholes.

4. If the total quantity of structural rock excavation is less than approximately 100 CY, the quantity will be shown as a non-bid item and the unit price established as six times the Structural Earth Excavation, Drainage and Minor Structures Below Grade unit price.

5. Use number 206.0707 for computer input when treating this item as a non-bid item.

206.14 Special Backfill - Cubic Yard

Special backfill is only estimated for those locations called for on the plans and is normally specified by the Bridge Program for use with larger structure. It can be called for in any location where circumstances dictate the use of a material having special properties which need to be defined.

304 Aggregate Base and Subbase

Element	Depths (typical)
Driveways	14-inch Aggregate Subbase (Unpaved) 12-inch Aggregate Subbase (Paved)
Sidewalks	12-inch Aggregate Subbase (Paved) 10-inch Aggregate Subbase (Concrete)
Foundations	2 feet
Slope Blanket	18 inches

304.08 Aggregate Base Course - Screened - Cubic Yard

304.09 Aggregate Base Course - Crushed - Cubic Yard

304.10 Aggregate Subbase Course - Gravel - Cubic Yard

304.11 Aggregate Subbase Course - Granular - Cubic Yard

304.12 Aggregate Subbase Course - Sand - Cubic Yard

Note: The method of measurement of each of the above items may be changed by adding .001, .002 or .003 to the item numbers. .001 indicates Lump Sum Measure; .002 indicates Pit measure; .003 indicates Truck Measure. Example: Item 304.102 Aggregate Subbase Course - Gravel - cubic yard (Pit Measure).

The designer should follow these procedures:

1. The major portion of the total amount of aggregate base or subbase course of the type specified to be estimated for a project may be derived from the quantities shown on the typical sections. These quantities must be calculated in conformity with the standard procedure for typical section calculations.

2. In addition to the typical section quantities, the following areas should be considered for a base or subbase course quantity:
   a. Driveways and sidewalks estimated by length, width and depth.
   b. Non-standard areas where typical sections do not apply generally estimated by length, width and depth, or plan area and depth.
   c. Variable depth bases and base shims these are generally estimated by using cross section areas and average end area volume computations methods.

3. Base and subbase depths and station-to-station limits must be shown on the typical section sheet. In addition, the station-to-station limits for each depth shall be shown on the cross sections.

4. The quantity of foundation material to be estimated for a project shall be determined in the following manner:

   a. From the soils report, field inspection plans, or general knowledge of the area involved, select the drainage structures that may warrant the use of foundation aggregate.

   b. Calculate the volume required using the length of culvert, maximum allowable trench width and a depth of 24 inches below the bottom of the pipe, unless known conditions require the use of a different depth.

   c. An equal amount of structural excavation should be estimated to provide a place for this material.

   d. Calculate the volume required for concrete steps as shown in the standard details and the volume required for slab walls or any other special usage.

Slope Blanket Protection

The quantity of aggregate for slope blanket is estimated to equal excavation for slope gravel blanket in cubic yards. Refer to Subsection 304.07, *Standard Specifications*, for basis of payment. It authorizes the use of aggregate base or subbase for slope blanket protection, bedding under drainage structures and other foundations, at twice the contract unit price for the respective material used. The Engineer's Estimate should separate these various uses and show them as a non-bid item. Call for aggregate subbase course of the type used on the project for roadway subbase material.

307. Full Depth Recycled Pavement - Square Yard

403.206 to 403.213 Hot Mix Asphalt - Ton (except as noted)

The designer should follow these procedures:

1. The type and thickness of pavement courses will be determined by the Geotechnical Engineer in cooperation with the 403 Specification Coordinator, based on traffic data and the design methods given in AASHTO Guide for Design of Pavement Structures.

2. The quantities of the various materials used are determined from the dimensions shown on the plans or ARAN output. There are 110 lbs/sy/inch of compacted depth (i.e., 1.98 ton/cy). If paving is done over two construction seasons, estimate 50 tons of shim per mile of lane.

3. The designer will make a written request to the 403 Specification Coordinator for the various types of materials to be used. This request shall also include a copy of the typical sections, which shall indicate the various depths and widths.

   3a. The Project manager will make a written request to the Planning Division, Research, for ARAN to Geotech for FWD data.

4. On overlay projects, estimate a 6-foot taper to match existing paved drives.

5. On overlay projects, estimate 3 foot x 1 inch quantity at all gravel driveways and entrance locations.

6. On non-overlay projects, estimate 3' foot x 2 inch quantity at all gravel driveways and entrance locations.

403.211 Hot Mix Asphalt, (Shimming) – Ton

Estimate 50 tons per mile per two lanes, undetermined location, for projects with hot mix asphalt when the paving will be done in two construction seasons. This item may also be used at varying rates on certain overlay projects.

409.15 Bituminous Tack Coat, Applied - Gallon

Emulsified Asphalt, Applied. The tack coat rate is specified in the Pavement Mix Design form furnished by the 403 Specification Coordinator.

410. Bituminous Surface Treatment

The type of bituminous surface treatment will be determined by the Project Manager. The quantities of the various materials used shall be determined from the dimensions and notes shown on the plans.

411.09 Untreated Aggregate Surface Course - Cubic Yard

411.10 Untreated Aggregate Surface Course, Truck Measure – Cubic Yard

The quantity of these items to be estimated shall be done in the same manner as aggregate base course. The item is normally used on resurfacing projects for shoulder and entrance grading. When estimating, increase the I.P.M. quantity by 15 percent to obtain the estimated Truck Measure quantity.

502.46 Structural Concrete Culvert Connection - Cubic Yard

The estimated volume shall be determined by the height, width and depth dimensions on the plans or in the special detail.

502.4711 Silica Fume Additive - Lump Sum

50 pounds per cubic yard concrete.

507.084 Steel Pipe Hand Railing – Lump Sum

Hand rail should be specified for each set of five or more steps. The quantity to be estimated shall be the total amount required as shown on the plans. Use the following table:

Required Length for the Number of Steps

No. of Step Risers	Length of Hand Rail (ft) Step Rise Ratio	
	12" Step/6"Rise	*12" Step/8"Rise*
5	5.5	5.8
6	6.6	7.0
7	7.7	8.2
8	8.8	9.4
9	9.9	10.6
10	11.1	11.8
11	12.2	13.0
12	13.3	14.2
13	14.4	15.4

509.11 to 509.411 Structural Plate Pipes and Pipe Arches - Lump Sum

The estimated cost of these items shall be determined by computing the mass of the structure as detailed on the plans and using a price per pound approved by the Bridge Design Section. The approximate mass of the structure in pounds shall be noted on the plans.

514.06 Curing Box for Concrete Cylinders - Each

This item should be considered but not automatically estimated whenever structural concrete is used on a project. The designer should check with the Bridge Design Division to see if the quantity of concrete and tests needed make this item necessary.

526.30 Temporary Concrete Barrier Type I – Linear Foot

526.301 Temporary Concrete Barrier Type I - Lump Sum

526.40 Resetting Temporary Concrete Barrier Type I – Linear Foot

These items will be estimated with assistance from the Design as part of the Traffic Control Plan (TCP).

601. Gabions and Mattresses - Cubic Yard

601.21 Gabions, Galvanized - Cubic Yard

601.22 Gabions, PVC Coated - Cubic Yard

601.221 Gabions, PVC Coated and Hand Filled - Cubic Yard

601.23 Mattresses, Galvanized - Cubic Yard

601.24 Mattresses, PVC Coated - Cubic Yard

The use of these items is normally recommended by the Design Division if a major drainage diversion is planned, a severe erosion potential exists, or minor earth retainments are needed. Details concerning proper placement should be obtained from the Bridge Design Division.

603. Pipe Culverts and Storm Drains – Linear Foot

Prior to making the estimate for pipe culverts, the designer should determine what options, if any, will be allowed the Contractor. The current available options and their intended usages are listed below.

For all fills of 10 feet or more from finished grade, reinforced concrete pipe shall be used. Adjacent to railroads, coated or non-coated corrugated metal which is one thickness greater than the thickness DOT would normally be used for the same installation. These heavier thickness pipes for R/R use should be given a separate pay item.

The designer should follow these procedures:

1. ***Culvert Option I.*** Under this option the Contractor may furnish any of the following types of pipe: Corrugated Steel, Metallic Coated Pipe; Reinforced Concrete Pipe; or any pipe allowed under Option III. The usage of this option is intended to be for entrance culverts only. See Figure 14-1 for typical culvert installation at entrances.

2. ***Culvert Option III.*** Under this option the Contractor may furnish any of the following types of pipe: Fiber-bonded Corrugated Steel Pipes, Corrugated Aluminum Alloy Pipe, Polyvinyl chloride (PVC) Pipe, Polymer Precoated Galvanized Corrugated Steel Pipe, or Reinforced Concrete Pipe. The usage of this option is intended to be for roadway culverts and other drainage structures. Estimate in increments of 4 feet.

3. ***Length (Option I).*** This shall be estimated in increments of 2 feet.

4. ***Length (Option III).*** This shall be estimated in increments of 4 feet, except when used in closed drainage systems. In closed drainage systems, the actual lengths should be measured to the nearest 1-foot from inside wall to inside wall of catch basins.

5. ***Temporary Culverts.*** These shall be estimated under the appropriate contract item, usually Pipe Option I. When removed under the same contract, it will become the property of the Contractor. The plans shall be noted to show whether it will be removed under the contract being estimated.

6. ***Induced Trench.*** Whenever the "Induced Trench" method of culvert installation is specified, an appropriate note on the cross sections should be added to make the cost of the trench backfill material incidental to the culvert.

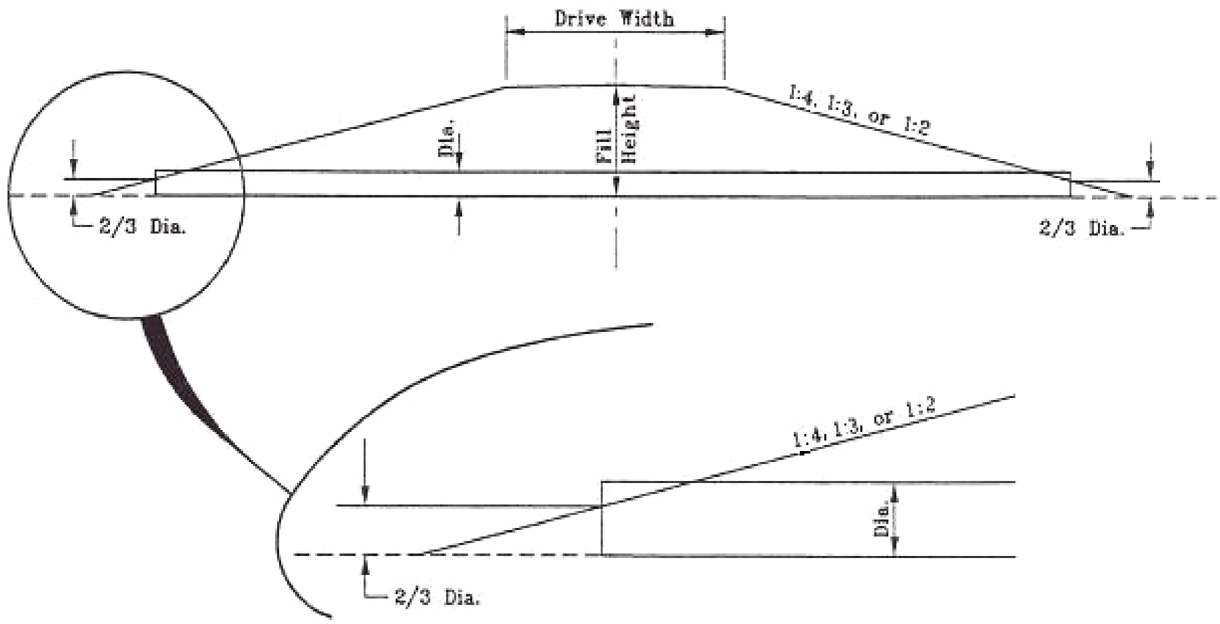
7. ***Item Nos./Sizes.*** The designer should refer to the Special Provisions to obtain the item numbers and pipe sized for the various pipe options.

8. ***Skewed Pipes.*** Particular care should be taken when estimating the length of skewed pipes under flat-sloped fills because the pipe and locations vary considerably with relatively small changes in the existing ground/or the template.

9. ***Strength/Class.*** The strength and class of each pipe should be checked and all special class pipes should be under individual pay items not under a standard culvert option.

10. ***Flexible Pipes.*** Flexible pipes 48 inches and larger on 2:1 slopes shall have ends cut to a partial bevel as shown in the Standard Details. Payment length for these pipes is the length along the invert of the installed pipe.

11. ***Elbows, Tees, Wyes.*** When elbows, tees, wyes or other special fittings are required in underdrain, or storm drain each fitting shall be included for payment as three additional linear feet of the largest pipe line involved.



Notes:

1. For estimate of culvert lengths, use 2-foot increments.
2. Maximum length of culvert shall not exceed 90 feet for 15”-diameter culverts.
3. For culvert lengths over 90 feet, use 18” to 24”-diameter culverts.

TYPICAL CULVERT INSTALLATION AT ENTRANCES

Figure 14-2

603.73 Remove and Relay Metal Pipe: (inch) Linear Foot

603.74 Remove and Relay Concrete Pipe: (inch) Linear Foot

The designer should follow these procedures:

1. The amount of metal pipe or concrete pipe to be estimated to be removed and relayed shall be that amount shown and noted on the plans and cross sections. The note on the plans and cross sections shall include both the station from which the culvert will be removed and the station where it is to be relayed.

2. The amount of culvert to be removed and relayed shall also be noted in the Drainage Summary Sheet.

3. Note that common excavation should be estimated for the removal of the culvert when the excavation is not covered by other items.

603.76 to 603.82 Inch Inlet Grate Unit – Each

The quantity of these items to be estimated for a project shall be the number of the required sizes that are shown and noted on the plans and cross sections. Inlet grates are normally used on basin stub pipes located where the unprotected stubs might create a hazard to the public.

604.072 to 604.15 & 604.242 to 604.262 Manholes and Catch Basins - Each

The designer should follow these procedures:

1. The number of manholes and catch basins of the applicable types to be estimated for a project shall be determined by the number shown and noted on the plans and cross sections. The designer should refer to the standard details and the specifications to obtain the item numbers and names for the various basins and manholes.

2. Each catch basin and manhole having a depth up to 8 feet from the top of the grate or cover to the top of the floor, measured to the nearest foot, will be one unit. One-eight of a unit will be added for each additional foot over 8 feet measured to the nearest foot.

3. The location and type of each manhole or catch basin shall also be shown in the Drainage Summary Sheet.

604.16 Altering Catch Basins to Manholes - Each

604.161 Altering Catch Basin - Each

604.164 Rebuilding Catch Basin - Each

604.166 Rebuilding Manhole - Each

-604.17 Altering Manholes to Catch Basins - Each

604.18 Adjusting Manhole or Catch Basin to Grade - Each

604.182 Clean Existing Catch Basin and Manhole - Each

The designer should follow these procedures:

1. The quantity of these items to be estimated for a project shall be the number of the catch basins or manholes that are so noted on the plans and cross sections.

2. Pay items 604.16 and 604.17 provide for alternating from one type structure to the other. Adjustment to a new grade can be included in the required work. Care should be taken to specify the desired frame and grate when using item 604.17.

3. Pay item 604.161 provides for the alteration of a catch basin to a different type frame and grate. Adjustment to a new grade is included in the required work.

4. Pay item 604.164 and 604.166 provide for removing and replacing frame, grate and cone.

5. Pay item 604.18 provides only for the adjustment of a catch basin or a manhole to a different grade.

6. Pay item 604.182 provides only for the cleaning of existing catch basins and manholes that will not be altered, adjusted or rebuilt. Payment for cleaning altered, adjusted or rebuilt catch basins is incidental to each respective pay item.

604.19 to 604.22 Inch Trap - Each

The quantity of these items to be estimated for a project shall be the number of the required sizes that are shown and noted on the cross sections. Traps should be used whenever the Department's

storm drainage system empties into the drainage systems of others, if that other system carries sewage or if the owner of the other system requests trap protection for his system.

604.23 Step - Each

The quantity of steps to be estimated for a project shall be the number that is noted on the cross sections to be installed in the specified catch basins or manholes. In general, the use of steps should be considered in any catch basin that is greater than 8 feet deep and in any manhole. The decision to use steps in either case shall be made by the Project Manager in conjunction with the Maintenance Division or local municipality.

Install steps 16 inches on center if CB or MH is over 8 feet in depth.

605.09 6-Inch Underdrain, Type "B" – Linear Foot

1. The quantity of underdrain, Type "B" to be estimated for a project shall be that amount shown and noted on the cross sections.

2. Underdrain locations shall be determined from the soils report, field inspection plans and Engineer's knowledge of the project being designed.

3. In addition to being shown and noted on the cross sections, underdrain shall be noted in the Drainage Summary Sheet.

4. The designer should be aware that not all municipalities allow all the various types of underdrain pipe that the Department does.

5. A quantity in addition to that required at known locations may be included in the estimate. This quantity should be estimated at about 50 percent of the length required to complete any "possible" underdrain locations as specified in the soils report. This added quantity should be designated as "undetermined location" on the quantity sheet.

6. Underdrain and underdrain outlets will be measured by the length in linear feet along the centerline of underdrains and underdrain outlets of the types and sizes completed and accepted.

7. When elbows, tees, wyes or other special fittings are required in underdrain, each fitting shall be included for payment as three additional feet of the largest pipe line involved.
8. Structural excavation shall be computed for the earthwork summary and general note.

605.10 6-Inch Underdrain Outlet – Linear Foot

The quantity of this item shall be estimated as required on the plans for outletting "B" U.D. For estimating the quantity in "Undetermined Locations," the quantity should be 8 percent of the length of Underdrain Type "B" designated "Undetermined Location" (see Item 605.09). Underdrain outlets are metal and require one delineator post each, clearly marked with a whole U.D. on a blue background.

605.11 12-Inch Underdrain, Type C – Linear Foot

605.12 15-Inch Underdrain, Type C – Linear Foot

605.13 18-Inch Underdrain, Type C – Linear Foot

605.14 21-Inch Underdrain, Type C – Linear Foot

605.15 24-Inch Underdrain, Type C – Linear Foot

605.17 30-Inch Underdrain, Type C – Linear Foot

605.18 36-Inch Underdrain, Type C – Linear Foot

The designer should follow these procedures:

1. The quantity of the various sizes of "Underdrain, Type C" to be estimated for a project shall be that amount shown and noted on the cross sections.

2. Underdrain locations shall be determined from the soils report, field inspection plans and the requirements of the storm water drainage system

3. In addition to being shown and noted on the cross sections, Underdrain Type "C" shall be noted in the Drainage Summary Sheet.

4. Outlet pipe for Type "C" Underdrain shall be estimated and noted as "Culvert Pipe, Option III" of the applicable size under Section 603.

5. The pipe for underdrains placed under or adjacent to railroads shall be coated or uncoated corrugated metal, which is one thickness greater than the thickness the Department

normally specified. This underdrain using heavier thickness pipe should be given a separate pay item.

Example: 605.111 12”Underdrain Type "C" – 0.079-inch Thick – linear foot

6. Comments concerning railroads and Type "B" U.D. also apply to Type "C" U.D. (see Item 605.09).

606.35 Underdrain Delineator Post - Each

This is a metal post to be installed at each Type B underdrain outlet location. The quantity estimated should be that number which is enough to provide posts as required by the project General Notes and/or as specifically noted on the plans.

606.353 Reflectorized Flexible Guardrail Marker – Each

This post to be installed at each guardrail installation. Two guardrail delineator posts shall be installed at each guardrail end. The quantity estimated should be that number which is enough to provide posts as required by the project General Notes and/or as specifically noted on the plans.

606.47 Single Wood Post - Each

606.51 - Multiple Mailbox Support - Each

These items will be used to provide mailbox posts for various field situations as shown in the standard details or as noted on the plan by the designer. The number of single posts for mailbox supports and the number of mailbox multiple supports shall be that number designated on the plans or general notes.

606 Guardrail – Linear Foot

606.15	Guardrail Type 3a - Single Rail
606.151	Guardrail Type 3aa - Single Rail
606.17	Guardrail Type 3b - Single Rail
606.171	Guardrail Type 3b - Single Rail with Rub Rail
606.19	Guardrail Type 3a - 15-Foot Radius and less
606.191	Guardrail Type 3aa -15-Foot Radius and less
606.20	Guardrail Type 3a - Over 15-Foot Radius

606.201	Guardrail Type 3aa - Over 15-Foot Radius
606.21	Guardrail Type 3b - 15-Foot Radius and less
606.22	Guardrail Type 3b - Over 15-Foot Radius
606.23	Guardrail Type 3c - Single Rail
606.24	Guardrail Type 3d - Single Rail
606.55	Guardrail Type 3 - Single Rail
606.551	Guardrail Type 3 - Single Rail with Rub Rail
606.59	Guardrail Type 3 - 15-Foot Radius and less
606.60	Guardrail Type 3 - Over15-Foot Radius

The designer should follow these procedures:

1. Currently, most projects call for Guardrail Type 3, which allows an option on the type of post and blocking to be used. If for some reason a top of rail mounting height of more than 27-inches is required, a rub rail should be added. (The designer is cautioned that a rub rail adds approximately 50 percent to the cost of the guardrail). Type 3aa Guardrail should be used if a rustic appearing steel beam guardrail is warranted.

2. The amount of guardrail of the above types to be estimated for a project shall be that amount shown and noted on the profile. Straight rail sections shall be called for and estimated in increments of 12.5 feet, when possible.

3. The amount of “Guardrail - Circular” to be estimated for a project shall be that amount shown and noted on the profile. “Beam Type Guardrail,” when placed on a curve of 150-foot radius or less, is designated and estimated as "Circular." When “Guardrail - Circular” is noted on the profile, the following information must be noted:

   a. station and offset to radius points,
   b. radius of curve required, and
   c. length of rail required.

   The radius of beam-type guardrail is 15 feet desirable and 10 feet minimum.

4. To make a 90 degree turn using guardrail, two 12.5-foot lengths of 16-foot radius does the job neatly.

5. When beam type guardrail will be connected to a bridge structure or bridge rail, the designer should refer to the bridge plans and the standard details for the correct guardrail layout.

606.16 Guardrail Type 3a - Double Rail
606.18 Guardrail Type 3b - Double Rail
606.181 Guardrail Type 3b - Double Rail with Rub Rail
606.56 Guardrail Type 3 - Double Rail
606.561 Guardrail Type 3 - Double Rail with Rub Rail

The designer should follow these procedures:

1. The amount of "Guardrail - Double Rail" to be estimated for a project shall be that amount noted on the plans.

2. In general, "Double Rail Guardrail" shall be used only in narrow medians.

606.173 Bridge Connection - Each
606.265 Terminal End - Single Rail - Galvanized Steel - Each
606.266 Terminal End - Single Rail - Corrosion Resistant Steel - Each
606.275 Terminal End - Double Rail - Galvanized Steel - Each
606.276 Terminal End - Double Rail - Corrosion Resistant Steel - Each

The designer should follow these procedures:

1. The number of "Terminal Ends" to be estimated shall be that number noted on the plans.

2. The “350 Terminal” is the usual guardrail end treatment. The other end treatments are normally used in special situations where the 350 is not used.

606.64 Guardrail Thrie Beam - Double Rail
606.65 Guardrail Thrie Beam - Single Rail
606.66 Terminal End Thrie Beam
606.67 Buffer End Thrie Beam
606.68 Buffer End Thrie Beam Modified
606.69 Flared End Thrie Beam
606.70 Transition Section - Thrie Beam
606.71 Guardrail Thrie Beam - 15-Foot Radius and less
606.72 Guardrail Thrie Beam - Greater than 15-Foot Radius

The amount of "Guardrail - Thrie Beam" to be estimated for a project shall be that amount noted on the profile sheets.

606.752 Widen Shoulder for Modified Eccentric Loader Terminal - Each

The amount of shoulder widening to be estimated for a project shall be that amount noted on the profile and cross section sheets. This item is normally used on overlay type projects. See Standard Detail Book page 606(19).

606.754 Guardrail - 350 Flared Terminal - Each

606.76 Modified Eccentric Loader Terminal - Each

606.79 Guardrail - 350 Flared Terminal

606.36 Guardrail - Removed and Reset - Linear Foot

606.362 Guardrail - Adjusted - Linear Foot

606.363 Guardrail - Remove and Dispose - Linear Foot

606.364 Guardrail - Remove, Modify and Reset, Type 3b - Linear Foot

The designer should follow these procedures:

1. Existing Steel Beam Guardrail in good condition may be considered for removal and resetting, adjusting, or removal, modifying and resetting.

2. The amount of guardrail to be estimated for these items shall be that amount noted on the profile and cross sections. The notes shall include both the removal stationing and, if applicable, the resetting station.

3. A Special Provision shall be written to cover the particular situation. All work anticipated for the completion of these items should be included, such as guardrail hardware, terminal ends, etc., as appropriate.

607. Fences

New Fencing - Controlled Access and Limited Access Freeways, Arterials and Collectors

The designer should follow these procedures:

1. In rural areas, fencing should be of the woven wire type on metal posts. Fences are required where the right of way passes through open field and pastures, farmland and intermittent wooded and brushy areas. Where woods roads occur in deeply wooded areas, guardrail should be installed across the entire traveled way portion of the roads in addition to fencing.

2. Public highways that have been severed should be fenced for a minimum distance of 200 feet from the highway in either direction, regardless of type of vegetation. Guardrail should be installed across the entire traveled way portion of the road in addition to fencing.

3. Utility right of way and trails used by rough terrain type vehicles shall be fenced for a minimum distance of 200 feet from the trail or utility right of way line.

4. In urban areas, six-foot chain link fence shall be installed where the right of way is adjacent to developed properties such as buildings, yards, playgrounds, residential areas and areas where people utilize the land routinely. Four-foot chain link fence shall be installed on controlled access facilities where pedestrian/bicycle use is permitted.

5. Station-to-station limits and side should be shown on the profile portion of the plan sheet.

Replacement Fencing

Replacement fencing for that which will be removed during the construction process will be provided on most projects.

Replacement installations should use the same type as now exists. Chain link fencing will be used in built-up urban areas. Station-to-station limits and side should be shown on the profile portion of the plan sheet.

607.08 Woven Wire Fence - Wood Posts - Linear Foot

607.09 Woven Wire Fence - Metal Posts - Linear Foot
607.10 Barbed Wire Fence - Wood Posts - Linear Foot

607.11 Barbed Wire Fence - Metal Posts - Linear Foot

607.12 Barway - Wood Posts - Each

607.13 Barway - Metal Posts - Each

607.14 Walk Gateway 4 Foot - Metal - Each

607.15 Drive Gateway 16 Foot - Metal - Each

The designer should follow these procedures:

1. The above items shall be called for on a replacement-in-kind basis.

2. "Drive Gateways, 16-foot, Metal" shall be called for in controlled access situations.

3. Note all gateway and barway locations on the profile portion of plan sheet.

4. The designer may call for a non-standard size, single or double swing gates, if for some good reason the standard 16-foot double swing gate can not be used. A special provision and pay item shall be developed if this is done.

607.16 Chain Link Fence – 4 Foot - Linear Foot

607.163 Chain Link Fence – 4 Foot, PVC Coated - Linear Foot

607.165 Chain Link Fence – 4 Foot, without Top Rail - Linear Foot

607.17 Chain Link Fence – 6 Foot - Linear Foot

607.173 Chain Link Fence – 6 Foot, PVC Coated -Linear Foot

607.175 Chain Link Fence – 6 Foot, without Top Rail - Linear Foot

The designer should follow these procedures:

1. The amount of chain link fence, of the applicable size, to be estimated for a project shall be that amount noted on the profile portion of a plan sheet.

2. On controlled access, high-volume urban highways which do not have sidewalks, the controlled right of way is normally fenced with 6-foot chain link fence, while on urban projects with no control of access, chain link fence is used for special areas as determined by the designer. An example of this special usage would be in front of a house on top of a long steep cut slope.

3. In medians and in clear zones, the top rail shall be omitted and be replaced with a galvanized steel wire.

607.22 Cedar Rail Fence - Linear Foot

The amount of Cedar Rail Fence to be estimated shall be that amount noted on the profile portion of the plans. This item will generally be used only for scenic turnouts, picnic areas and replacement in kind.

607.2311 through 607.2339 Chain Link Fence Gate - Each

The number of chain link fence gates to be estimated shall be that number of specific sizes noted on the profile portion of the plans. Normally, the designer should use a standard 4-, 6-, 8-, 10-, 12- or 14-foot wide gate. If for some good reason none of these standard widths can be used, the designer may call for some other width by special provision and pay for it under a special pay item. For 6-foot chain link fence, a 20-foot wide gate is available. For 8-foot chain link fence, a 20-foot and 24-foot wide gate is available.

607.24 Remove and Reset Fence - Linear Foot

607.25 Remove and Reset Chain Link Fence - Linear Foot

The designer should follow these procedures:

1. The amount of fencing to be estimated to be removed and reset shall be that amount noted on the plans. The notes on the plans shall include both the removal stations as well as the resetting stations.

2. The use of Item 629.05, Labor, Straight Time, may be used instead of this item. This decision will be made by the Project Manager.

607.30 Bracing Assembly, Type I - Wood Posts - Each

607.31 Bracing Assembly, Type II - Wood Posts - Each

607.32 Bracing Assembly, Type I - Metal Posts - Each

607.33 Bracing Assembly, Type II - Metal Posts - Each

The designer should follow these procedures:

1. At changes in horizontal and vertical alignment in excess of 30 degrees, bracing will be required. At changes in horizontal and vertical alignment of 15 degrees to 30 degrees, bracing may be called for on the plans or required by the Engineer. At changes in horizontal and vertical alignment angles of less than 15 degrees, bracing will not be required, except at intervals of 660 feet.

2. In depressions where tension in the fencing may cause lifting, the post will require bracing.

3. End, corner, gate, barway and intermediate posts shall be braced and anchored as shown in the Standard Detail book.

4. Note that when "Gateways - Metal" are used, the adjacent bracing assemblies shall be metal regardless of the post type used for the fencing.

607.34 Bracing Assembly, Chain Link Fence - Each

607.35 Bracing Assembly, Chain Link Fence - PVC Coated - Each

The designer should follow these procedures:

1. Fences less than 6-foot in height that are installed with a top rail shall not require any brace rails. Fences less than 6-foot in height installed without a top rail and all fences with heights of 6-foot or more shall have brace rails installed midway between the top and bottom of the fabric as shown on the plans. At changes in horizontal alignment of less than 15 degrees, bracing will not be required, except at intervals of 330 feet. At changes in alignment of 15 degrees to 30 degrees, bracing may be required. At changes in alignment in excess of 30 degrees, bracing will be required for all fencing.

2. One brace assembly shall be furnished with each end or gate post and two assemblies with each corner or intermediate post and at grade changes specified above.

608.07 Plain Concrete Sidewalk - Square Yard

608.08 Reinforced Concrete Sidewalk - Square Yard

The designer should follow these procedures:

1. The use of these items shall generally be limited to the replacement of existing facilities in urban areas.

2. The width and length shall be noted on the plans and cross sections.

3. All necessary excavation and aggregate base material should be estimated under the applicable item.

608.XXX Truncated Domes - Square Feet

Detectable Warning Field shall be placed in Pedestrian Ramp and/or an Entrance with sufficient traffic. Detectable Warning Field will be measured by actual in place dimensions.

609.11 to 609.35 Curbing - General (Types 1, 3 and 5) - Linear Foot

Normal usage is as follows:

1. Type 1 (vertical granite curb) is used on well developed urban highways which carry moderate to heavy traffic volume, at locations adjacent to sidewalks, edges of paved shoulders or travel lanes, and for side street approach radii. Also, sometimes Type 1 is used in places where bituminous curb is otherwise warranted, but it is felt that the bituminous curb would not be able to withstand possibly expected hard usage.

2. Type 3 (bituminous curb) is used for box sections built in rural areas with low to moderate traffic volumes; on the low side of a banked curve in guardrail sections; and to delineate islands, sidewalks and parking areas where the usage is expected to be light duty. In general, mold 1 is used adjacent to sidewalks and mold 2 elsewhere. The minimum radius for Type 3 curb is 5 feet.

3. Type 5 (sloped granite curb) is used in moderate to heavy duty usage areas for traffic islands, raised medians, speed change lane edge delineation, island nose delineation, loop ramps with less than a 300-foot radius, ramp terminals and channelized intersections.

4. Reference should be made to the *Standard Specifications* and Standard Details to ensure that the proper type of curb, transition sections, terminal curbs and circular curb called for in the estimate are properly classified.

5. The quantity of curb of the applicable types to be estimated for a project is that amount shown and noted on the plans.

6. When a long run of curb is broken at frequent intervals by drives and entrances, it will not be necessary to station each curb break. It will be sufficient to station the long run of curb and, then, in the Engineer's Estimate subtract entrance openings, terminal transition, catch basin header curb and curb-cut ramp openings on the plans.

7. Vertical Curb Type 1 placed on a radius of 60 feet or less, will be paid for as Vertical Curb Type 1 - Circular.

8. Curb, Type 5, placed on a radius of 30 feet or less, will be paid for as Curb Type 5-Circular.

9. Circular curb must be detailed with the following information:

   a. station and offset of radius point, and of the beginning and end, accurately computed;

   b. radius of curve; and

   c. length of curve, to be computed accurately, is very important in all cases, and even more so in the case of islands involving compound curves.

10. Terminal curb should be listed on the plans.

609.38, 609.39 and 609.40 Resetting Curb - Linear Foot

The designer should follow these procedures:

1. These items include the quantity of removing and resetting existing curb of the type shown on the plans. The plans must be noted (profile section) with the location from which the curb will be removed and the location where it will be reset.

2. In addition to curb reset due to dislocation, it may be advisable to estimate a reasonable quantity for adjacent side streets where base and/or pavement is being matched. In many cases stone curbing on these side streets is in good material condition but badly out of line, and it would spoil the effect of the new work unless corrected.

610.07 Stone Fill - Cubic Yard

610.08 Plain Riprap - Cubic Yard

The designer should follow these procedures:

1. The amount of plain riprap to be estimated for a project shall be that amount required for the usages specified on the plans and cross sections.

2. Riprap shall be estimated for all culvert inlets and outlets except entrance culverts when erosion control measures are required. The amount of riprap to be estimated for culvert end protection may be found in Tables 14-1 and 14-2. The amount to be estimated for U.D. outlets is a pad 3-foot square.

3. Use of riprap shall generally be confined to drainage ways where the slope is steep (over six percent with substantial flow) such as downspouts, roadway ditches going abruptly from cut to fill, culvert outlets which are much steeper than the culvert grade, and at the outlets of culvert on relatively steep grades.

4. The locations where plain riprap is required, except as noted in the general project notes and shown in the standard details, shall be noted on the plans.

5. The depth of plain riprap shall be estimated as 18 inches.

610.09 Hand Laid Riprap - Cubic Yard

The designer should follow these procedures:

1. The amount of hand laid riprap to be estimated for a project shall be that amount required for usages specified on the plans and cross sections.

2. This item will generally be used in special cases as approved by the Project Manager.

610.16 Heavy Riprap - Cubic Yard

The designer should follow these procedures:

1. These items may be used to provide embankment protection in tidal areas and along sides of rivers and streams where the potential for erosion is probable. Stone fill should be used in place of plain riprap when the designer desires stones of a larger size than required for plain riprap.

   Note: Larger stones are less subject to dislodgment by ice, debris and swift moving water.

2. Normal stone fill installations will be 3 feet to 5 feet thick and should have a 2-foot thick filter of gravel borrow placed between the stone fill and the embankment to prevent the loss of embankment material due to water action.

3. Estimate cubic yard in place measure (I.P.M.) as shown on the plans and cross sections.

Culvert Diameter (inches)	Riprapped End (Cubic Yards)
12	0.97
15	1.09
18	1.19
21	1.29
24	1.43
30	1.65
36	1.90
42	2.15
48	2.40
54	2.66
60	2.90

Note: Quantities are for one end of culvert.

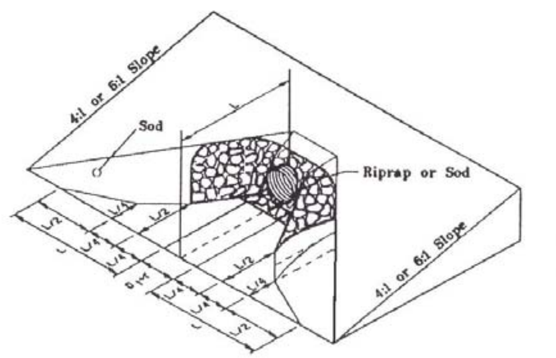
FACTORS FOR ESTIMATING CULVERT END PROTECTION
(1:2 Slope)

Table 14-1

Culvert Diameter (inches)	Cubic Yards Riprap		
	1:6 Slope	***1:4 Slope***	***1:3 Slope***
18	3.11	2.44	2.19
21	3.17	2.56	2.26
24	3.27	2.70	2.41
30	3.89	3.33	3.06
36	4.89	4.33	4.05
42	6.11	5.56	5.28
48	7.73	7.12	6.81
54	9.44	8.89	8.62
60	11.67	10.78	10.33
66	13.72	13.00	12.65
72	16.33	14.63	13.79
84	21.22	19.11	18.06

Notes:

1. Quantities are for one end of culvert.
2. Riprapped area is on slopes 1:1 and steeper.
3. See Standard Detail Book page 800(22) for more information.



FACTORS FOR ESTIMATING CULVERT END PROTECTION
(Riprapped Ends)

Table 14-2

610.18 Stone Ditch Protection - Cubic Yard

The designer should follow these procedures:

1. The amount of stone ditch protection to be estimated for a project shall be that amount required on the plan and cross sections, except as noted in the General Notes. The depth of stone shall be estimated at one foot.

2. The locations where stone ditch protection will generally be is in roadside ditches that are on a six percent or greater grade, with a high concentration of runoff.

611.161 Segmental Retaining Wall - Square Yard

613. Erosion Control Blankets

0 to 2% - Use an erosion control blanket in high flow.
2 to 6% - Use an erosion control blanket.

613.319 Temporary Erosion Control Blanket - Square Yard

613.329 Extended Use Erosion Control Blankets - Square Yard

These items should be used in ditches where the slope of the ditch is less than six percent. The amount to be estimated will be by the square yard, based on the width and length of the roll of blanket prior to installation. Item 613.329 is used only when called for by the Landscape Section.

614.18 Applying Fertilizer To Existing Grassed Areas

Use of this item shall be recommended by Landscape.

615.07 Loam - Cubic Yard

The designer should follow these procedures:

1. The amount of loam to be estimated for a project shall be that amount required to loam lawn areas specified on the plans and/or cross sections measured in place. The depth of loam shall be estimated at four inches unless specified differently.

2. Optional areas such as cut backslopes and fill slopes will be reviewed by the Highway Program, in conjunction with the Landscape Architect (utilize soils report), to determine as accurately as possible where any additional loam will be used. All definite areas should be so noted on the plans. Because it will be impossible to accurately pinpoint all loamed or unloamed areas, it will probably be necessary to estimate some loam for undetermined locations.

3. The designer's attention is directed to that portion of Section 615 of the *Standard Specifications* which states that, when designated on the plans or directed, the Contractor shall salvage loam within the lines of improvement in both excavation and embankment areas. Areas from which salvaged topsoil will be estimated will be determined by the Project Manager during the final field inspection.

4. Those areas from which topsoil will be salvaged shall be designated in the General Notes. Salvaged topsoil depths shall be assumed to be the same as the depths estimated for grubbing as specified in Section 203.20 of this Section and paid for as Common Excavation.

618.13 Seeding, Method Number 1 - Unit

618.14 Seeding, Method Number 2 - Unit

618.141 Seeding, Method Number 3 - Unit

The designer should follow these procedures:

1. Seeding Method No. 1 will be used on lawns, large traffic islands and developed medians.

2. Seeding Method No. 2 will be used on all non-guardrail foreslopes from the edge of shoulder to the ditch line or toe of fill.

3. Seeding Method No. 3 will be used on all 2:1 backslopes and on all guardrail fill slopes.

4. Seeding should be estimated for all earth cut and fill slopes that are not going to be covered by other erosion control methods.

5. The quantity of these items is to be estimated as measured along the slope of the finished ground in units of 1000 square feet.

6. In addition to the above described quantity on rural projects, an additional 5 feet width shall be added to all Method No. 2 areas to provide for additional disturbed areas beyond the slope lines and the unavoidable extra areas seeded.

618.17 Reed Canary Grass Seed - Pounds

618.191 Birdsfoot Trefoil Seed - Pounds

The designer should follow these procedures:

1. These items are used to supplement mixture Method No. 2 and should only be used when requested by the Landscape Section.

2. The amount to be estimated per unit of seeding (1000 square feet) is as follows:

   Crown Vetch Seed – 1.5 lbs/unit
   Reed Canary Grass Seed – 0.5 lbs/unit
   Birdsfoot Trefoil Seed – 1.5 lbs/unit

618.19 Refertilization - pounds

The designer should follow these procedures:

1. This item is used to strengthen existing grass growth on a project and should only be estimated as requested by the Department's Landscape Section.

2. The amount to be estimated is 8 lbs/unit for 20 percent of Seeding No. 1, No. 2 and No.3 quantities.

618.20 Annual Rye - pounds

Estimate 0.5 lbs/unit for 25% of the Seeding No. 2 and No. 3 quantities.

618.25 Applied Water - Cubic Yard

Estimate 45 gal/unit for 10% of the Seeding No. 1, No. 2 and No. 3 quantities. If calculated quantity is less than 500 gallons, do not include item in contract. If calculated quantity is greater than 500 gallons, round up to the Engineer's Estimate minimum quantity of 1 M.G.

619.12 Mulch - Unit

The designer should follow these procedures:

1. Mulch is used on all areas seeded by Methods No. 1, No. 2 and No. 3. Mulch for seeding pits and temporary seeding should also be estimated.

2. Estimate one unit for each 1000 square feet.

3. For extra mulch for temporary use, estimate an extra 25% of the Seeding No. 1, No. 2 and No. 3 quantities, when requested by Landscape.

620. Geotextiles

The designer should follow these procedures. The amount to be estimated will be by the square yard.

620.54 Stabilization Geotextile - Square Yard

For use to stabilize subgrade. Its use will be designated by the Department's Geotechnical Section in the Soils Report.

620.56 Drainage Geotextile - Square Yard

For use in underdrain trenches. Its use will be designated by the Department's Geotechnical Section in the Soils Report.

620.58 Erosion Control Geotextile - Square Yard

For use under all riprap.

621. Landscaping

The designer should follow these procedures:

1. Whenever items under Section 621 will be used on highway construction, the designer shall consult with the Department's Landscape Section before completing the design to review specifications, item numbers and item description.

2. The quantity to be estimated shall be that amount of the respective items noted on the plans.

622.09 Transplanting Hedge - Linear Foot

622.10 Transplanting Shrub - Each

622.11 Transplanting Tree - Each

The designer should follow these procedures:

1. All hedges, shrubs and small trees shown on the plans outside the existing right-of-way lines which are in good condition and in the way of construction should normally be considered for transplanting.

2. Prior to estimating any hedge, shrub or tree to be transplanted, the Department's Landscape Section should be consulted to obtain their recommendations as to the feasibility of the transplant under consideration and, if their recommendation is positive, the Right-of-Way Division should be consulted to determine its opinion of the owner's desires in the matter.

3. The classification of the transplanted item (e.g., hedge, shrub or tree) must be clearly shown on the plans to avoid any confusion in the basis of payment to the Contractor.

623. and 624. Monuments and Markers - Each

These items are still available in the specifications but are not used on projects unless directed to do so.

625.08 _____-Inch Copper Tubing - Linear Foot

625.10 _____-Inch Non-Metallic Pipe (flexible) - Linear Foot

625.14 _____-Inch Pipe Sleeve - Linear Foot

The designer should follow these procedures:

1. These items singly or in combination are used to replace, sleeve, repair or provide new water service lines when directed by the Project Manager, as requested by the Right of Way Team Member.

2. The designer is cautioned to notify the Right-of-Way Team Member of all existing pipes, which will be disturbed by the proposed construction.

3. The amount to be estimated shall be that amount noted on the plans. Because the use of these items is generally requested by the Right-of-Way Team Member, coordination between Divisions is necessary.

626.11 - 626.38 Foundations, Conduit and Junction Boxes for Highway Signing, Lighting and Signals

These items should be used when signing, lighting or traffic signals will be used on the project. The estimate and design of the above work will be supplied by the Traffic Engineering Division.

627. Pavement Markings

Pavement markings will be included on all projects. The estimate for this work shall be done by the Project Manager with help from the Traffic Engineering Division.

629.05 Labor - Straight Time - Man-Hour

This item will **only** be estimated for work as called for on the plans. There appears to be no possible way to accurately estimate the amount of this item that will be required for a particular project. Therefore, the estimated quantity for this item will be determined on a project-by-project basis by the Project Manager and reviewed by the Construction Team Member.

When using Temporary Silt Fence on a project, estimate 25 MH per mile for removing the silt and sediment.

Equipment Rental - Per Hour

631.09 Aerator (Including Operator and Hauler) - Hour
631.10 Air Compressor (Including Operator) - Hour
631.11 Air Tool (Including Operator) - Hour
631.12 All Purpose Excavator (Including Operator) - Hour
631.121 Heavy Duty All Purpose Excavator (Including Operator) - Hour
631.13 Bulldozer (Including Operator) - Hour
631.132 Small Bulldozer (Including Operator) - Hour
631.14 Grader (Including Operator) - Hour
631.15 Roller, Earth & Base Course (Including Operator) - Hour
631.16 Roller, Pavement (Including Operator) - Hour
631.171 Truck - Small (Including Operator) - Hour
631.172 Truck - Large (Including Operator) - Hour
631.18 Chain Saw Rental (Including Operator) - Hour
631.20 Stump Chipper Rental (Including Operator) - Hour
631.21 Road Broom (Including Operator and Hauler) - Hour
631.22 Front End Loader (Including Operator) - Hour
631.221 Small Front End Loader (Including Operator) - Hour
631.29 Rototiller (Including Operator) - Hour
631.32 Culvert Cleaner (Including Operator) - Hour
631.36 Foreman - Hour

The designer should follow these procedures:

1. These items will only be estimated for work as called for on the plans. Unforeseen work will be taken care of on a Force Account basis using "Blue Book" rates.

2. The estimated quantity will be that amount to complete the work as called for on the plans as determined by the Project Manager and reviewed by the Construction Team Member.

3. When using Temporary Silt Fence on a project, use the following items and factors to estimate quantities: 10 hrs per mile for Item 631.12 and 15 hrs per mile for Item 631.172.

634. Highway Lighting

635. Prefabricated Bin Type Retaining Wall

635.10 Concrete Bin Type Retaining Wall, Closed Face - Square Yard

635.11 Concrete Bin Type Retaining Wall, Open Face - Square Yard

635.12 Galvanized Metal Bin Type Retaining Wall - Square Yard

635.13 Galvanized Metal Bin Type Retaining Wall with Fiber Coating - Square Yard

These items are used to provide earth retainment when directed by the Project Manager as recommended by the Bridge Team Member. The Bridge Program will normally provide the necessary detailed designs and estimated quantities involved when these items are used.

636. Reinforced Soil Wall

639.18 Field Office Type "A" - Each

639.19 Field Office Type "B" - Each

The Construction Team Member will recommend to the Project Manager the requirement of providing or not providing a field office on the project. If a field office is required, the following is a guide in selecting the type:

1. ***Type A*.** Use when there is a bridge on a highway project and when a computer is required on the project.

2. ***Type B*.** Use when a computer is not required on a highway project.

The Construction Division has adopted the following rules for determining if computers are required on a project. Use a computer when:

1. electricity is available,
2. the duration of the project is over 3 months (60 working days),
3. there are at least 30 pay items in the Contract, <u>and</u>
4. the total estimated cost of the project is:

a.	highway reconstruction/rehabilitation:	over $250,000
b.	resurfacing:	over $350,000
c.	bridge construction/rehabilitation:	over $350,000
d.	miscellaneous:	over $1,000,000

Note: <u>All</u> four criteria <u>must</u> be met.

<u>639.21 Testing Facilities, Soils - Lump Sum</u>

Required whenever the aggregate material (excluding common borrow and excavation) exceeds 20,000 cubic yards or 15,000 cubic yards when there are 2 or more types of aggregate requiring gradations.

<u>639.23 Testing Facilities, Concrete - Lump Sum</u>

Required whenever a) the total quantity of structural concrete exceeds 10 cubic yards, or b) the estimated number of foundations (summation of items 626.31, 626.32 and 626.33) exceeds 10.

<u>642.12 Wooden Steps - Each</u>

<u>642.15 Precast Concrete Steps - Each</u>

<u>642.17 Cast-in-place Concrete Steps - Cubic Yard</u>

The designer should follow these procedures:

1. These specialty items shall be used when directed by the Project Manager as normally requested by the Right-of-Way Team Member as a property settlement.

2. The width, rise ratio, and number of steps will be noted on the plans. Tables 14-3 and 14-4 provide the estimated quantities from Standard Detail Book page 642(01). Non-standard designs should be referred to the Bridge Design Program for design details

and, if the volume of concrete is less than 5 CY$\pm$, a non-standard design may be bid on a lump-sum basis including all materials and work.

3. Other related items to be estimated for steps, except when bid Lump Sum, will be:

   a. aggregate subbase for foundation or granular borrow, and
   b. estimate bedding material volume to the limits given for structural excavation.

No. of Intersteps	**Width of Steps (ft)**									
	3	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
Footer/Header	0.25.	0.31	0.37	0.43	0.49	0.55	0.61	0.67	0.73	0.79
1	0.38	0.47	0.56	0.65	0.74	0.83	0.92	1.01	1.10	1.19
2	0.51	0.63	0.75	0.87	0.99	1.11	1.23	1.35	1.47	1.59
3	0.64	0.79	0.94	1.09	1.24	1.39	1.54	1.69	1.84	1.99
4	0.77	0.95	1.13	1.31	1.49	1.67	1.85	2.03	2.21	2.39
5	0.90	1.11	1.32	1.53	1.74	1.95	2.16	2.37	2.58	2.79
6	1.03	1.27	1.51	1.75	1.99	2.23	2.47	2.71	2.95	3.19
7	1.16	1.43	1.70	1.97	2.24	2.51	2.78	3.05	3.32	3.59
8	1.29	1.59	1.89	2.19	2.49	2.79	3.09	3.39	3.69	3.99
9	1.42	1.75	2.08	2.41	2.74	3.07	3.40	3.73	4.06	4.39
10	1.55	1.91	2.27	2.63	2.99	3.35	3.71	4.07	4.43	4.79
11	1.68	2.07	2.46	2.85	3.24	3.63	4.02	4.41	4.80	5.19
12	1.81	2.23	2.65	3.07	3.49	3.91	4.33	4.75	5.17	5.59
13	1.94	2.39	2.84	3.29	3.74	4.19	4.64	5.09	5.54	5.99
14	2.07	2.55	3.03	3.51	3.99	4.47	4.95	5.43	5.91	6.39
15	2.20	2.71	3.22	3.73	4.24	4.75	5.26	5.77	6.28	6.79

VOLUME FOR CONCRETE STEPS (ft^3)
(1:2 Slope ~ 12" Step/6" Rise)

Table 14-3

No. of Intersteps	**Width of Steps (ft)**									
	3	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
Footer/Header	0.29	0.36	0.43	0.50	0.57	0.64	0.71	0.78	0.85	0.92
1	0.45	0.55	0.66	0.76	0.87	0.97	1.08	1.18	1.29	1.39
2	0.60	0.74	0.88	1.02	1.16	1.30	1.44	1.58	1.72	1.86
3	0.75	0.93	1.10	1.28	1.45	1.63	1.80	1.98	2.15	2.33
4	0.91	1.12	1.33	1.54	1.75	1.96	2.17	2.38	2.59	2.80
5	1.06	1.30	1.55	1.79	2.04	2.28	2.53	2.77	3.02	3.26
6	1.21	1.49	1.77	2.05	2.33	2.61	2.89	3.17	3.45	3.73
7	1.37	1.68	2.00	2.31	2.63	2.94	3.26	3.57	3.89	4.20
8	1.52	1.87	2.22	2.57	2.92	3.27	3.62	3.97	4.32	4.67
9	1.67	2.06	2.44	2.83	3.21	3.60	3.98	4.37	4.75	5.14
10	1.82	2.24	2.66	3.08	3.50	3.92	4.34	4.76	5.18	5.60
11	1.98	2.43	2.89	3.34	3.80	4.25	4.71	5.16	5.62	6.07
12	2.13	2.62	3.11	3.60	4.09	4.58	5.07	5.56	6.05	6.54
13	2.28	2.81	3.33	3.86	4.38	4.91	5.43	5.96	6.48	7.01
14	2.44	3.00	3.56	4.12	4.68	5.24	5.80	6.36	6.92	7.48
15	2.59	3.18	3.78	4.37	4.97	5.56	6.16	6.75	7.35	7.94

VOLUME FOR CONCRETE STEPS (cy^3)
(1.15:1 Slope ~ 12" Step/8" Rise)

Table 14-4

643. Traffic Signals

645. Highway Signing

The Traffic Engineering Division will prepare the design of the required installations and will provide the required specifications. Reference should be made to the project specifications and the details furnished by the Traffic Engineering Division for correct item numbers, item names, methods of measurement and basis of payment.

Note: The designer should be careful to check the location of the proposed installations to determine if there is any conflict with the proposed curbs, drainage, islands, etc.

652. Maintenance of Traffic

652.30 Flashing Arrow Board - Each

652.31 Type I Barricades - Each

652.311 Type II Barricades - Each

652.312 Type III Barricades - Each

652.32 Battery Operated Light - Each

652.33 Drum - Each

652.34 Cone - Each

652.35 Construction Signs - Square Yard

652.36 Maintenance of Traffic Control Devices - Calendar Day

652.361 Maintenance of Traffic Control Devices - Lump Sum

652.37 Warning Lights - Group

652.38 Flaggers - Man-Hours

653.20 1 inch Polystyrene Plastic Insulation - Square Yard

653.21 1 ½ inch Polystyrene Plastic Insulation - Square Yard

653.22 2 inch Polystyrene Plastic Insulation - Square Yard

653.23 3 inch Polystyrene Plastic Insulation - Square Yard

These items will be estimated for a project only when designated by the Project Manager in cooperation with the Geotechnical Section. When used, these items shall be shown on the typical sections, and the proposed locations noted on the plans. The quantity to be estimated shall be that amount shown on the plans.

Ditch Type	Typical Number Per Installation	
	Hay Bales	Sand Bags
4:1-2:1 V Ditches	3	3
6:1-3:1 V Ditches	4	3
6:1-3:1 Circular Ditches	5	3

Percent Grade of Ditch	Typical Spacing Along The Ditch
< 3%	100 ft
3.5 %	75 ft
> 5%	50 ft

656.75 Temporary Soil Erosion and Water Pollution Control – Lump Sum

This item shall be estimated on all projects that require a Temporary Soil Erosion and Water Pollution Control Plan (SEWPCP).

657.24 Seeding Pits - Unit

This item is used to rehabilitate pits, sod fields and loam borrow areas. The Project Manager will review the quantity of this item and determine if this item will be a bid item or made incidental to the contract. The current Engineer's Estimate factors used to compute this item are:

1. Loam borrow areas: 1 unit/20 yards of loam removed (based on 6.5" depth)
2. Aggregate borrow areas: Estimated average 10-foot pit depth.

658.20 Acrylic Latex Color Finish, Green - Square Yard

This item is used to place a green colored finish on asphalt surfaces such as medians, islands, etc. The amount to be estimated shall be the number of square yards of area to be treated, as designated on the plans and/or in the General Notes. Care should be taken to deduct the area of the curbs.

659.10 Mobilization - Lump Sum

This item will be used on all projects to allow payment to a Contractor for moving onto the project. The Project Manager should confer with the Construction Team Member when estimating this item.

660.21 On-the-Job Training (bid) - Man-Hour

This item will be used as estimated and directed by the Contracts Section.

14-3 RULES FOR ROUNDING

This section presents rounding and adjustment factors (not covered in Section 14-2) which apply to estimating construction quantities.

1. ***Types***. There are two types of quantities:

   a. Quantities from Counting: Examples include trees, single posts, etc.

   b. Quantities from Calculations: Examples include excavation, portland cement concrete, loam, etc.

2. ***Counted Items.*** The estimated quantity shall be the actual total count as taken from the plans.

3. ***Calculated Quantities***. The following rules shall apply:

   a. Total quantities less than 1.0 may be rounded upward not more than 0.1 unit.

   b. Total quantities of 1 but less than 10 may be rounded upward not more than 0.5 unit.

   c. Total quantities of 10 but less than 100 may be rounded upward not more than 1 unit.

   d. Total quantities of 100 but less than 1,000 may be rounded upward not more than 10 units.

   e. Total quantities of 1,000 but less than 10,000 may be rounded upward not more than 50 units.

   f. Total quantities of 10,000 shall be rounded to the nearest third significant figure.

Appendix 14A

ENGINEER'S ESTIMATE WORKSHEET

MDOT

ENGINEER'S ESTIMATE WORKSHEET

TOWN OR CITY ____

CONSTR. PROJECT NO. ____________________ ***P.I.N.*** ____________________

COUNTY ______________________________ ***ROUTE NO.*** ______________

ESTIMATE BY ____

LENGTH ______________________________ ***MILES***

1. ***PARTICIPATING - NON PARTICIPATING***

2. ***HIGHWAY ITEMS***

2. ***BRIDGE ITEMS*** ____________________ ***BRIDGE LENGTH*** ________ ***FEET***
(NAME) ***(BACK TO BACK OF BACKWALL)***

2. ______________________________ ***ITEMS***

2. ______________________________ ***ITEMS***

SHEET TOTAL____________

December 2004

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
107.27	TEMPORARY EROSION AND WATER CONTROL	LS			
201.11	CLEARING	ac / ha			
201.12	SELECTIVE CLEARING AND THINNING	ac / ha			
201.23	REMOVING SINGLE TREE TOP ONLY	EA			
201.24	REMOVING STUMP	EA			
202.08	REMOVING BUILDING # ________	LS			
202.09	REM EXISTING SUPERSTRUCTURE-RETAINED BY DEPT	LS			
202.1	REM EXISTING SUPERSTR-PROP OF CONTR	LS/ft^3/m^3			
202.11	REM PORTLAND CEMENT CONCRETE PAVEMENT	ft^2 / m^2			
202.12	REMOVAL OF EXISTING STRUCTURAL CONCRETE	ft^3 / m^3			
202.121	REMOVING EXISTING CONCRETE	LS / m^3			
202.123	SCARIFYING CONCRETE DECKTOP_____inches/mm	LS/ft^2/m^2			
202.128	REMOVING EXISTING CONC-CURBS & SIDEWALKS	LS/ft^3/m^3			
202.19	REMOVING BRIDGE	LS/ft^3/m^3			
202.202	REMOVING PAVEMENT SURFACE	ft^2 / m^2			
202.203	PAVEMENT BUTT JOINTS	ft^2 / m^2			
203.2	COMMON EXCAVATION	ft^3 / m^3			
203.202	INSLOPE EXCAVATION	ft / m			
203.203	DITCH EXCAVATION	f t /m			
203.21	ROCK EXCAVATION	ft^3 / m^3			
203.2107*	ROCK EXCAVATION	ft^3 / m^3			
203.22	UNCLASSIFIED EXCAVATION	ft^3 / m^3			
203.24	COMMON BORROW	ft^3 / m^3			
203.242	DIRTY BORROW	ft^3 / m^3			
203.25	GRANULAR BORROW	ft^3 / m^3			
203.26	GRAVEL BORROW	ft^3 / m^3			
203.29	SELECTED GRANULAR MATERIAL	ft^3 / m^3			

* Non-Bid Items

SHEET TOTAL --

December 2004

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
204.41	REHAB EXISTING SHOULDER, PLAN QUANITY	ft^2 / m^2			
205.41	RECONSTRUCT EXISTING SHOULDER, PLAN QUANTITY	ft^2 / m^2			
206.061	STR EARTH EXCV-DRAIN & MINOR STRUC, BELOW GRAD	ft^3 / m^3			
206.07	STRUCTURAL ROCK EXCV-DRAIN & MINOR STRUC	ft^3 / m^3			
206.082	STRUCTURAL EARTH EXCV-MAJOR STRUCT	ft^3 / m^3			
206.092	STRUCTURAL ROCK EXCV-MAJOR STRUC	ft^3 / m^3			
206.1	STRUCTURAL EARTH EXCAVATION-PIERS	ft^3 / m^3			
206.11	STRUCTURAL ROCK EXCAVATION-PIERS	ft^3 / m^3			
304.08	AGGREGATE BASE COURSE-SCREENED	ft^3 / m^3			
304.083	AGGREGATE BASE COURSE-SCREENED, TRUCK MEAS	ft^3 / m^3			
304.09	AGGREGATE BASE COURSE-CRUSHED	ft^3 / m^3			
304.093	AGGREGATE BASE COURSE CRUSHED, TRUCK MEAS	ft^3 / m^3			
304.1	AGGREGATE SUBBASE COURSE-GRAVEL	ft^3 / m^3			
304.103	AGGREGATE SUBBASE COURSE-GRAVEL, TRUCK MEAS	ft^3 / m^3			
304.11	AGGREGATE SUBBASE COURSE-GRANULAR	ft^3 / m^3			
304.113	AGGR SUBBASE COURSE-GRANLR, TRUCK MEAS	ft^3 / m^3			
304.12	AGGREGATE SUBBASE COURSE-SAND	ft^3 / m^3			
304.123	AGGREGATE SUBBASE COURSE-SAND, TRUCK MEAS	ft^3 / m^3			
307.3	COLD IN-PLACE RECYCLED MATERIAL	ft^2 / m^2			
307.31	COLD IN-PLACE RECYCLED BITUMINOUS MATERIAL	gal / L			
307.32	COLD IN-PLACED RECYCLED MATERIAL TRAVELWAY	ft^2 / m^2			
307.33	COLD IN-PLACED RECYCLED MATERIAL SHOULDER	ft^2 / m^2			
403.207	HOT MIX ASPHALT 19.0 mm	Tn / Mg			
403.208	HOT MIX ASPHALT 12.5mm SURFACE	Tn / Mg			
403.209	HOT MIX ASPHALT 9.5mm (INCD.)	Tn / Mg			
403.21	HOT MIX ASPHALT 9.5 mm	Tn / Mg			
403.211	HOT MIX ASPHALT (SHIM)	Tn / Mg			

* Non-Bid Items

SHEET TOTAL --

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
403.213	HOT MIX ASPHALT 12.5mm BASE	Tn / Mg			
409.15	BITUMINOUS TACKCOAT, APPLIED	gal / L			
411.09	UNTREATED AGGREGATE SURFASE COURSE	ft^3 / m^3			
411.11	UNTREATED AGGRG SURFACE COURSE, TRK MEAS	ft^3 / m^3			
411.12	CRUSHED STONE SURFACE	Tn/Mg			
424.31	JOINT & CRACK SEALER-POLYSTER FIBER	gal / L			
424.32	ASPHALT RUBBER CRACK SEALER	gal / L			
424.33	ASPHALT RUBBER CRACK SEALER & ROUTING	gal / L			
424.34	ASPHALT FIBER CRACK SEALER	gal / L			
424.35	ASPHALT FIBER CRACK SEALER & ROUTING	gal / L			
425.2	HOT RECYCLED PAVEMENT	Tn / Mg			
460.22	HOT BITUMINOUS PAVEMENT	Tn / Mg			
501.23	LOADING TEST	EA			
501.36	STEELE H-BEAM PILES 36 lb/ft (53 kg/m)	f t /m			
501.38	STEELE H-BEAM PILES 42 lb/ft (62 kg/m)	f t /m			
501.4	STEELE H-BEAM PILES 53 lb/ft (79 kg/m)	f t /m			
522.06	MODULR EXPANSION DEVICES	EA			
526.3	TEMPORARY CONCRETE BARRIER TYPE I	f t /m			
526.301	TEMPORARY CONCRETE BARRIER TYPE I	LS			
526.31	PERMANENT CONCRETE BARRIER TYPE III	f t /m			
526.32	PERMANENT CONCRETE BARRIER TYPE III	f t /m			
526.4	RESETTING TEMPORARY CONCRETE BARRIER TYPE I	f t /m			
527.3	ENERGY ASORBING SYSTEM (G-R-E-A-T)	EA			
527.301	ENERGY ASORBING SYSTEM (C-A-T)	EA			
527.32	PORTABLE CRASH BARRELS	EA			
535.6	PRESTRESSED STRUCTURAL CONCRETE SLAB	LS/ft^2/m^2			
535.61	PRESTRESSED STRUCTURAL CONCRETE I-GIRDERS	LS/ft/m			

* Non-Bid Items

SHEET TOTAL ---

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
601.21	GABIONS, GALVANIZED	ft^3 / m^3			
601.22	GABIONS, PVC COATED	ft^3 / m^3			
601.23	MATTRESSES, GALVANIZED	ft^3 / m^3			
601.24	MATTRESSES, PVC COATED	ft^3 / m^3			
603.15	12" (300-mm) CULVERT PIPE OPTION I	f t /m			
603.159	12" (300-mm) CULVERT PIPE OPTION III	f t /m			
603.16	15" (375-mm) CULVERT PIPE OPTION I	f t /m			
603.161	15" (375-mm) CORRUGATED METAL PIPE	f t /m			
603.169	15" (375-mm) CULVERT PIPE OPTION III	f t /m			
603.17	18" (450-mm) CULVERT PIPE OPTION I	f t /m			
603.171	18" (450-mm) CORRUGATED METAL PIPE	f t /m			
603.179	18" (450-mm) CULVERT PIPE OPTION III	f t /m			
603.18	21" (525-mm) CULVERT PIPE OPTION I	f t /m			
603.181	21" (525 mm) CORRUGATED METAL PIPE	f t /m			
603.189	21" (525 mm) CULVERT PIPE OPTION III	f t /m			
603.19	24" (600 mm) CULVERT PIPE OPTION I	f t /m			
603.191	24" (600 mm) CORRUGATED METAL PIPE	f t /m			
603.199	24" (600 mm) CULVERT PIPE OPTION III	f t /m			
603.2	30" (750 mm) CULVERT PIPE I	f t /m			
603.201	30" (750 mm) CORRUGATED METAL PIPE	f t /m			
603.209	30" (750 mm) CULVERT PIPE OPTION III	f t /m			
603.21	36" (900 mm) CULVERT PIPE OPTION I	f t /m			
603.211	36" (900 mm) CORRUGATED METAL PIPE	f t /m			
603.219	36" (900 mm) CORRUGATED PIPE OPTION III	f t /m			
603.221	42" (1050 mm) CORRUGATED METAL PIPE	f t /m			
603.229	42" (1050 mm) CULVERT PIPE OPTION III	f t /m			
603.231	48" (1200 mm) CORRUGATED METAL PIPE	f t /m			

* Non-Bid Items

SHEET TOTAL --

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
603.239	48" (1200 mm) CULVERT PIPE OPTION III	f t /m			
603.249	54" (1350 mm) CULVERT PIPE OPTION III	f t /m			
603.259	60" (1500 mm) CULVERT PIPE OPTION III	f t /m			
603.269	66" (1650 mm) CULVERT PIPE OPTION III	f t /m			
603.279	72" 1800 mm) CULVERT PIPE OPTION III	f t /m			
603.289	84" (2100 mm) CULVERT PIPE OPTION III	f t /m			
603.___	____inches(mm) SPAN___inches(mm) RISE___ PIPE ARCH	f t /m			
603.___	____inches(mm) SPAN___inches(mm) RISE ___PIPE ARCH	f t /m			
603.___	_____inches(mm) REINF CONCRETE PIPE CLASS IV	f t /m			
603.___	_____inches(mm) REINF CONCRETE PIPE CLASS IV	f t /m			
603.___	_____inches(mm) REINF CONCRETE PIPE CLASS V	f t /m			
603.723	CUTTING CORRUGATED METAL PIPE	EA			
603.73	REMOVE AND RELAY METAL PIPE	f t /m			
603.74	REMOVE AND RELAY CONCRETE PIP	f t /m			
603.___	_____inches(mm) INLET GRATE UNIT	EA			
604.07	CATCH BASIN TYPE A1	EA			
604.07__	CATCH BASIN TYPE A1-	EA			
604.08	CATCH BASIN TYPE A2	EA			
604.08__	CATCH BASIN TYPE A2-	EA			
604.09	CATCH BASIN TYPE B1	EA			
604.09__	CATCH BASIN TYPE B1-	EA			
604.1	CATCH BASIN TYPE B2	EA			
604.10__	CATCH BASIN TYPE B2-	EA			
604.11	CATCH BASIN TYPE C1	EA			
604.12	CATCH BASIN TYPE C2	EA			
604.13	24"(600mm) CATCH BASIN TYPE E	EA			
604.14	30"(750mm) CATCH BASIN TYPE E	EA			

* Non-Bid Items

SHEET TOTAL --

December 2004

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
604.15	MANHOLE	EA			
606.16	ALTERING CATCH BASIN TO MANHOLE	EA			
604.18	ADJUSTING MANHOLE OR CATCH BASIN TO GRADE	EA			
604.___	_____inches(mm) TRAP	EA			
________	ALTER CATCH BASIN TO TYPE:	EA			
604.24	CATCH BASIN TYPE F	EA			
604.24__	CATCH BASIN TYPE F-_____	EA			
604.25	CATCH BASIN TYPE A5	EA			
604.25__	CATCH BASIN TYPE A5-___	EA			
604.26	CATCH BASIN TYPE B5	EA			
604.26__	CATCH BASIN TYPE B5-___	EA			
605.09	6" (150mm) UNDERDRAIN TYPE B	ft / m			
605.1	6" (150mm) UNDERDRAIN OUTLET	ft / m			
605.11	12" (300mm) UNDERDRAIN TYPE C	ft / m			
605.12	15" (375) mm UNDERDRAIN TYPE C	ft / m			
605.13	18" (450 mm) UNDERDRAIN TYPE C	ft / m			
605.14	21" (525 mm) UNDERDRAIN TYPE C	ft / m			
605.15	24" (600 mm) UNDERDRAIN TYPE C	ft / m			
605.17	30" (750 mm) UNDERDRAIN TYPE C	ft / m			
606.16	GUARDRAIL TYPE 3a-SINGLE RAIL	ft / m			
606.151	GUARDRAIL TYPE 3aa-SINGLE RAIL	ft / m			
606.152	GUARDRAIL TYPE 3ab-SINGLE RAIL	ft / m			
606.16	GUARDRAIL TYPE 3b-DOUBLE RAIL	Lf/Lm			
606.17	GUARDRAIL TYPE 3b-SINGLE RAIL	ft / m			
606.1731	BRIDGE CONNECTION TYPE I	EA			
606.1732	BRIDGE CONNECTION TYPE II	EA			
606.178	GUARDRAIL BEAM	ft / m			

* Non-Bid Items

SHEET TOTAL --

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
606.18	GUARDRAIL TYPE 3b-DOUBLE RAIL	ft / m			
606.19	GUARDRAIL TYPE 3a-15ft (4.5m) RADIUS AND LESS	ft / m			
606.191	GUARDRAIL TYPE 3aa-15ft (4.5m) RADIUS AND LESS	ft / m			
606.192	GUARDRAIL TYPE 3ab-15ft (4.5m)) RADIUS AND LESS	ft / m			
606.2	GUARDRAIL TYPE 3a-OVER 15ft (4.5m) RADIUS	ft / m			
606.201	GUARDRAIL TYPE 3aa-OVER 15ft (4.5m) RADIUS	ft / m			
606.202	GUARDRAI TYPE 3ab-OVER 15ft(4.5m) RADIUS	ft / m			
606.21	GUARDRAILTYPE 3b-15ft (4.5m) RADIUS AND LESS	ft / m			
606.22	GUARDRAIL TYPE 3b-OVER 15ft (4.5m) RADIUS	ft / m			
606.265	TERMINAL END-SINGLE RAIL-GALVANIZED STEEL	EA			
606.266	TERMINAL END-SINGLE RAIL-CORROSION RESIST STEEL	EA			
606.275	TERMINAL END DOUBLE RAIL-GALVANIZED STEEL	EA			
606.276	TERMINAL END DOUBLE RAIL-CORROSION RESIST STEEL	EA			
606.35	UNDER DRAIN DELINEATOR POST	EA			
606.351	GUARDRAIL DELINEATOR POST REMOVE & RESET	EA			
606.353	REFLECTORIZED FLEXIBLE GUARDRAIL MARKERS	EA			
606.355	GUARDRAIL MOWING DELINEATORS	EA			
606.357	GUARDRAIL, MODIFY, TYPE 3b	ft / m			
606.36	GUARDRAIL, REMOVE AND RESET	ft / m			
606.362	GUARDRAIL, ADJUSTED	ft / m			
606.363	GUARDRAIL, REMOVE & DISPOSE	ft / m			
606.364	GUARDRAIL, REMOVE, MODIFY AND RESET TYPE 3b	ft / m			
606.367	REPLACE UNUSABLE EXISTING GUARDRAIL POST	ft / m			
606.369	GUARDRAIL, REMOVED AND STACKED	ft / m			
606.47	SINGLE WOOD POST	EA			
606.5	SINGLE STEEL PIPE POST	EA			
606.51	MULTIPLE MAILBOX POST	EA			

* Non-Bid Items

SHEET TOTAL ---

December 2004

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
606.55	GUARDRAIL TYPE 3-SINGLE RAIL	ft / m			
606.56	GUARDRAIL TYPE 3-DOUBLE RAIL	ft / m			
606.564	GUARDRAIL TYPE 3 DBL RAIL, REM & RESET	ft / m			
606.565	GUARDRAIL TYPE 3 DBL RAIL, REM, MOD & RESET	ft / m			
606.59	GUARDRAIL TYPE 3-15ft (4.5m) RADIUS AND LESS	ft / m			
606.6	GUARDRAIL TYPE 3-OVER 15ft (4.5m) RADIUS	ft / m			
606.621	MODIFY EXISTING TWISTED END SECTION	EA			
606.751	WIDEN SHOULDER FOR BREAKAWAY CABLE TERM	EA			
606.752	WIDEN SHOULDER FOR MOD.ECCENTRIC LOADER TERM	EA			
606.754	WIDEN SOULDER FOR 350 END TREATMENT	EA			
606.77	REMOVE AND RESET BCT	EA			
606.79	GUARDRAIL 350 FLARED TERMINAL	EA			
606.771	BREAKAWAY CABLE TERMINAL, REMOVE AND RESET	EA			
607.08	WOVEN WIRE FENCE-WOOD POSTS	ft / m			
607.09	WOVEN WIRE FENCE-METAL POSTS	ft / m			
607.1	BARBED WIRD FENCE-WOOD POSTS	ft / m			
607.11	BARBED WIRD FENCE-METAL POSTS	ft / m			
607.12	BARWAY-WOOD POSTS	EA			
607.13	BARWAY-METAL POSTS	EA			
607.1__	WALK GATEWAY_____ft/m-METAL	EA			
607.1___	DRIVE GATEWAY_____ft/m-METAL	EA			
607.1___	CHAIN LINK FENCE_____ft/m	in / mm			
607.23	CHAIN LINK FENCE GATE	EA			
607.24	REMOVE AND RESET FENCE	ft / m			
607.3	BRACING ASSEMBLY TYPE I-WOOD POSTS	EA			
607.31	BRACING ASSEMBLY TYPEII-WOOD POSTS	EA			
607.32	BRACING ASSEMBLY TYPE I-METAL POSTS	EA			

* Non-Bid Items

SHEET TOTAL --

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
607.33	BRACING ASSEMBLY TYPE II-METAL POSTS	EA			
607.3___	BRACING ASSEMBLY TYPE I-CHAIN LINK FENCE___ft/m	EA			
607.3___	BRACING ASSEMBLY TYPE II-CHAIN LINK FENCE____ft/m	EA			
608.____	CONCRETE SIDEWALK	ft^2 / m^2			
608.____	TRUNCATED DOMES	ft^2 / m^2			
609.12	VERTICAL CURB TYPE 1-CIRCULAR	ft / m			
609.13	VERTICAL BRIDGE CURB TYPE 1	ft / m			
609.131	VERTICAL BRIDGE CURB TYPE 1A	ft / m			
609.132	VERTICAL BRIDGE CURB TYPE 1B	ft / m			
609.133	VERTICAL BRIDGE CURB SPECIAL	ft / m			
609.14	VERTICAL BRIDGE CURB TYPE 1-CIRCULAR	ft / m			
609.23	TERMINAL CURB TYPE 1	EA			
609.234	TERMINAL CURB TYPE 1 - 4ft (1.2m)	EA			
609.237	TERMINAL CURB TYPE 1 - 7ft (2.1m)	EA			
609.237	TERMINAL CURB TYPE 1 - 7ft (2.1m) CIRCULAR	EA			
609.238	TERMINAL CURB TYPE 1 - 8ft (2.4m)	EA			
609.26	CURB TRANSITION SECTION B TYPE 1	EA			
609.31	CURB TYPE 3	ft / m			
609.34	CURB TYPE 5	ft / m			
609.35	CURB TYPE 5-CIRCULAR	ft / m			
609.38	RESET CURB TYPE 1	ft / m			
609.4	RESET CURB TYPE 5	ft / m			
610.07	STONE FILL	ft^3 / m^3			
610.08	PLAIN RIPRAP	ft^3 / m^3			
610.09	HAND LAID RIPRAP	ft^3 / m^3			
610.11	STONE BLANKET	ft^3 / m^3			
610.16	HEAVY RIPRAP	ft^3 / m^3			

* Non-Bid Items

SHEET TOTAL ---

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
610.18	STONE DITCH PROTECTION	ft³ / m³			
611.___	SLAB FOR BACKSLOPE PROTECTION	ft² / m²			
613.319	TEMPORARY EROSION CONTROL BLANKET	ft² / m²			
613.329	EXTENDED USE EROSION CONTROL BLANKET	ft² / m²			
614.18	APPLYING FERTILIZER TO EXISTING GRASSED AREAS	lb / kg			
615.07	LOAM	ft³ / m³			
617.3	COMPOSTED BARK MIX	ft³ / m³			
618.13	SEEDING METHOD NUMBER 1	UN			
18.1301	SEEDING METHOD NUMBER 1-PLAN QUANTITY	UN			
618.14	SEEDING METHOD NUMBER 2	UN			
618.1401	SEEDING METHOD NUMBER 2-PLAN QUANTITY	UN			
618.141	SEEDING METHOD NUMBER 3	UN			
618.1411	SEEDING METHOD NUMBER 3-PLAN QUANTITY	UN			
618.142	SEEDING METHOD NUMBER 4	UN			
618.15	TEMPORARY SEEDING	kg			
618.16	CROWN VETCH SEED	kg			
618.17	REED CANARY GRASS SEED	kg			
618.191	BIRDSFOOT TREFOIL SEED	kg			
618.2	ANNUAL RYE GRASS SEED	kg			
618.25	APPLIED WATER	ft³ / m³			
619.12	MULCH	UN			
619.1201	MULCH - PLAN QUANTITY	UN			
619.13	BARK MULCH	UN			
620.54	STABILIZATION GEOTEXTILE	ft² / m²			
620.55	STABILIZATION GEOTEXTILE (SEWN SEAMS)	ft² / m²			
620.56	DRAINAGE GEOTEXTILE	ft² / m²			
620.57	DRAINAGE GEOTEXTILE (SEWN SEAMS)	ft² / m²			

* Non-Bid Items

SHEET TOTAL --

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
620.58	EROSION CONTROL GEOTEXTILE	ft^2 / m^2			
620.59	EROSION CONTROL GEOTEXTILE (SEWN SEAMS)	ft^2 / m^2			
620.6	REINFORCEMENT GEOTEXTILE	ft^2 / m^2			
620.61	REINFORCEMENT GEOTEXTILE (SEWN SEAMS)	ft^2 / m^2			
621.___					
621.___					
622.___	TRANSPLANTING	ft / m			
625.08__	_____inches(mm) COPPER TUBING	ft / m			
625.10__	_____inches(mm) NON-METALLIC PIPE (FLEXIBLE)	ft / m			
625.14__	_____inches(mm) PIPE SLEEVE	ft / m			
626.11__	PRECAST CONCRETE JUNCTION BOX	EA			
626.11__	PRECAST CONCRETE JUNCTION BOX	EA			
626.21	METALLIC CONDUIT	ft / m			
626.22	NON METALLIC CONDUIT	ft / m			
626.23	PREWIRE CONDUIT SECONDARY WIRING	ft / m			
626.24	PREWIRE CONDUIT PRIMARY WIRING	ft / m			
626.31	18" (450-mm) FOUNDATION	EA			
626.32	24" (600-mm) FOUNDATION	EA			
626.33	30" (750-mm) FOUNDATION	EA			
626.34	SIGNAL POLE FOUNDATION	EA			
626.35	CONTROLLER CABINET FOUNDATION	EA			
626.36	REMOVE OR MODIFY CONCRETE FOUNDATION	EA			
626.37	SPECIAL FOUNDATION	EA			
626.38	GROUND MOUNTED CABINET FOUNDATION	EA			
627.407	REFLECTORIZED PLASTIC, WHITE OR YELLOW PAVEMENT MARKING	ft^2 / m^2			
627.4071	REFLECTORIZED PLASTIC, WHITE OR YELLOW PAVEMENT MARKING, PLAN QUANTITY	ft / m			

* Non-Bid Items

SHEET TOTAL --

December 2004

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
627.711	WHITE OR YELLOW, PAVEMENT MARKING LINE, PLAN QUANTITY	ft / m			
627.75	WHITE OR YELLOW PAVEMENT AND CURB MARKING	ft^2 / m^2			
627.76	TEMPORARY PAVEMENT MARKING LINE, WHITE OR YELLOW	LS			
627.811	TEMP BI-DIRECTIONAL YELLOW DELINEATORS	EA			
629.05	HAND LABOR, STRAIGHT TIME	MH			
*630.0607	TRAFFIC CONTROLLERS	MH			
631.09	AERATOR (INCLUDING OPERATOR AND HAULER)	HR			
631.1	AIR COMPRESSOR (INCLUDING OPERATOR)	HR			
631.11	AIR TOOL (INCLUDING OPERATOR)	HR			
631.12	ALL PURPOSE EXCAVATOR (INCLUDING OPERATOR)	HR			
631.13	BULLDOZER (INCLUDING OPERATOR)	HR			
631.131	SMALL BULLDOZER-GRADER (INCLUDING OPERATOR)	HR			
631.132	SMALL BULLDOZER (INCLUDING OPERATOR)	HR			
631.14	GRADER (INCLUDING OPERATOR)	HR			
631.15	ROLLER EARTH OR BASE COURSE (INCL. OPERATOR)	HR			
631.16	ROLLER, PAVEMENT (INCLUDING OPERATOR)	HR			
631.171	TRUCK-SMALL (INCLUDING OPERATOR)	HR			
631.172	TRUCK-LARGE (INCLUDING OPERATOR)	HR			
631.18	CHAIN SAW RENTAL (INCLUDING OPERATOR)	HR			
631.2	STUMP CHIPPER RENTAL (INCLUDING OPERATOR)	HR			
631.21	ROAD BROOM (INCLUDING OPERATOR)	HR			
631.22	FRONT END LOADER (INCLUDING OPERATOR)	HR			
631.29	ROTOTILLER (INCLUDING OPERATOR)	HR			
631.32	CULVERT CLEANER (INCLUDING OPERATOR)	HR			
634.16	HIGHWAY LIGHTING	LS			
634.164	LUMINARIES FOR HIGH MAST LIGHTING	EA			

* Non-Bid Items

SHEET TOTAL ---

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
634.206	LIGHT STANDARD FOR POST TOP LUMINAIRE	EA			
634.207	HIGH MAST LIGHT STANDARD	EA			
634.209	WOOD ORNAMENTAL LIGHT STANDARD	EA			
634.21	CONVENTIONAL LIGHT STANDARD	EA			
635.12	GALVANIZED METAL BIN TYPE RETAINING WALL	ft^2 / m^2			
638.01	EMBEDDED WORK IN STRUCTURES	LS			
638.02	NAVIGATION LIGHTS	LS			
638.021	TEMPORARY NAVIGATION LIGHTING	LS			
639.18	FIELD OFFICE TYPE A	EA			
639.19	FIELD OFFICE TYPE B	EA			
639.21	TESTING FACILITIES SOILS	LS			
639.23	TESTING FACILITIES CONCRETE	LS			
642.16	PRECAST CONCRETE STEPS	ft/m			
642.17	CAST-IN-PLACE CONCRETE STEPS	ft^3 / m^3			
643.6	FLASHING BEACON AT	LS			
643.71	TRAFFIC SIGNAL MODIFICATION	LS			
643.72	TEMPORARY TRAFFIC SIGNAL	LS			
643.8	TRAFFIC SIGNAL AT	LS			
643.9	INTERCONNECT WIRE BETWEEN	LS			
645.103	DEMOUNT GUIDE SIGN	EA			
645.106	DEM REGUL WARN CONFIRM & RTE MARK ASSY SIGN	EA			
645.108	DEMOUNT POLE	EA			
645.113	REINSTALL EXISTING GUIDE SIGN	EA			
645.116	REINST REGU, WARN, CONF, & RTE MARK ASSY SIGN	EA			
645.118	REINSTALL POLE	EA			
645.12__	OVERHEAD GUIDESIGN	LS			
645.13__	GUIDE SIGN-OVERPASS MOUNTED	LS			

* Non-Bid Items

SHEET TOTAL --

December 2004

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
645.15	CANTILEVER GUIDE SIGN	LS			
645.251	ROADSIDE GUIDE SIGNS, TYPE I	ft² / m²			
645.261	BRIDGE GUIDE SIGNS, TYPE I	ft² / m²			
645.271	REG WARN CONF & RTE MARKER ASSY SIGNS TYPE I	ft² / m²			
645.280__	______inches(mm) ALUMINUM POLE	EA			
645.280__	______inches(mm) ALUMINUM POLE	EA			
645.289	STEEL H-BEAM POLES	lb / kg			
645.291	ROADSIDE GUIDE SIGNS TYPE II	ft² / m²			
645.292	REG, WARN, CONF & RTE MARK ASSY SIGN TYPE	ft² / m²			
645.301	DEMOUNTABLE REFLECTORIZED DELINEATOR, SINGLE	EA			
645.302	DEMOUNTABLE REFLECTORIZED DELINEATOR, DOUBLE	EA			
645.303	DEMOUNTABLE REFLECTOR DELINEATOR, TRIPLE	EA			
645.5	PROJECT SIGNING	LS			
652.25	MAINTENANCE OF TRAFFIC	LS			
652.3	FLASHING ARROW BOARD	EA			
652.31	TYPE I BARRICADE	EA			
652.311	TYPE II BARRICADE	EA			
652.312	TYPE III BARRICADE	EA			
652.32	BATTERY-OPERATED LIGHT	EA			
652.33	DRUM	EA			
652.34	CONE	EA			
652.35	CONSTRUCTION SIGNS	ft² / m²			
652.36	MAINTENANCE OF TRAFFIC CONTROL DEVICES	CD			
652.361	MAINTENANCE OF TRAFFIC CONTROL DEVICES	LS / CD			
652.37	WARNING LIGHTS	Group			
652.38	FLAGGER	MH			
653.____	____inches(mm) POLYSTYRENE PLASTIC INSULATION	ft² / m²			

* Non-Bid Items

SHEET TOTAL --

PROJECT ESTIMATE WORKSHEET

ITEM NO.	DESCRIPTION	UNIT	QTY	UN PRICE	AMOUNT
656.75	TEMPORARY SOIL EROSION & W.P. CONTROL	LS			
657.24	SEEDING PITS (USE ONLY WHEN > 20 UNITS)	UN			
658.2	ACRYLIC LATEX COLOR FINISH, GREEN	ft^2 / m^2			
659.1	MOBILIZATION (___________%)	LS			
660.21	ON-THE-JOB TRAINING (BID)	MH			

* Non-Bid Items

SHEET TOTAL ---

PROJECT DEVELOPMENT PROCESS

SHEET ~ 1 ~ TOTAL	
SHEET ~ 2 ~ TOTAL	
SHEET ~ 3 ~ TOTAL	
SHEET ~ 4 ~ TOTAL	
SHEET ~ 5 ~ TOTAL	
SHEET ~ 6 ~ TOTAL	
SHEET ~ 7 ~ TOTAL	
SHEET ~ 8 ~ TOTAL	
SHEET ~ 9 ~ TOTAL	
SHEET ~ 10~ TOTAL	
SHEET ~ 11 ~ TOTAL	
SHEET ~ 12 ~ TOTAL	
SHEET ~ 13 ~ TOTAL	
SHEET ~ 14 ~ TOTAL	
SHEET ~ 15 ~ TOTAL	
GRAND TOTAL	

CHAPTER FIFTEEN

FLEXIBLE DESIGN PRACTICES

Volume I

- Highway Design Guide –

National Standards

March 2006

Chapter Fifteen

TABLE OF CONTENTS

Definitions -

NHS – National Highway System

AASHTO – American Association of State Highway Transportation Officials

Green Book – AASHTO – A policy on Geometric Design of Highways and Streets

Traffic Calming - Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non motorized street users.

Local Street – Provides direct driveway access to adjacent properties within residential neighborhoods. Generally, local streets have low speeds and volumes.

Minor Collector – Collects and distributes traffic between local streets and major collectors and/or the arterial system. Minor collectors provide more of a land access function than mobility.

Major Collector – Major collectors emphasize mobility over land access, distributing traffic between major traffic generators or minor collectors and the arterial system.

Minor Arterial – Minor arterials are designed to emphasize mobility over land access, providing access to principal arterials (highways and freeways). They connect cities with adjacent communities and the highway system.

15-1 INTRODUCTION

The Goal of this chapter is to enhance the essence of small, close-knit rural communities in Maine by providing a safe, attractive and comfortable pedestrian environment in a Village while celebrating its unique historic, built and natural features. The challenge is to upgrade road conditions through the Village by meeting Federal Highway System requirements to provide better sight lines and improved vehicular and pedestrian safety while respecting the aesthetic and socio-economic fabric of the community. MaineDOT's technical staff needs to ensure that proposed aesthetic improvements do not interfere with surface drainage patterns, access to underground utilities, and the maximum and minimum grades allowed on roadways. The process is collaborative in nature and draws on time-honored traditions of public meetings, civil discourse and representative democracy. Participation by professionals like artists, landscape architects and others can infuse the process with a creative approach to problem solving and openness to new solutions. A Local Review Committee can provide needed input by overseeing the Project from conceptual design to construction and installation and through to maintenance.

In pursuing this goal, it is important to remember that the full range of the design parameters are available for utilization within AASHTO and the MaineDOT Highway Design Guide.

This "Flexible Design Practices" chapter is not a new design standard. The chapter provides examples of existing design standards and the design exception process. It is intended to provide advice and guidance in complying with Congressional direction that highway design, particularly on the NHS, be flexible and accommodating when sensitive areas are involved such as state highways that run through villages. For projects not on the NHS, Congress has provided that States have the flexibility to develop and apply criteria they consider appropriate. Here in Maine, this has been accomplished with the publication of the MaineDOT Highway Design Guide, Volume II, State Standards (for Maine Non-National Highway System).

Because this "Flexible Design Practices" chapter does not contain any new design criteria, it relies on the criteria provided in the AASHTO "Green Book", the FHWA publication "Flexible Design Practices" and other current design guidelines.

The major thrust of this new chapter is to encourage and foster the development of an attitude toward greater flexibility in the use of specific design policies, procedures and standards. Its goal is to enhance creativity and sensitivity toward the community, historic and cultural values, while providing for user safety and efficiency in highway operations.

Users of this manual are encouraged to share any new solutions you may have found to particular design issues with your colleagues. In addition, if you think the new solution you have found should be included in the future versions of the chapter, please forward your suggestions to the Program Manager of the Highway Program, Maine Department of Transportation, 16 State House Station, Augusta, Maine. In this way, you will be expanding the knowledge base and contributing to successful context sensitive design.

Today's sponsors of transportation improvements consider an extraordinary array of factors. These include not only functionality, safety, and cost but the many concerns of a wide collection of stakeholders, and an extensive range of environmental, cultural, and community issues. This design process succeeds if it has credibility with highway engineers, planners, landscape architects, environmental and historic preservation staff, and the community. It must ring true with all. This means that: those primarily concerned with engineering factors and functionality appreciate the benefits of a broader design context; that designers willingly and openly seek the flexibility necessary to achieve a balanced outcome that respects the imperatives of both technical functionality and context sensitivity; and that planners, landscape architects, environmental staff, and the community have a heightened awareness of the legitimate concerns and constraints with which design engineers must deal.

15-1.1 Understanding Community Needs

Community needs vary widely but typical expressions of local concerns include the following:

- Pavement requires major repair
- Drainage is not functioning
- Traffic volumes are high and cause congestion
- Traffic speeds are too high for the setting
- Crashes are a concern
- Street lacks character and needs improvement in the form of landscaping, street furniture, reduction of overhead utilities, etc.
- Parking is inadequate
- Too few or too many poles and signs
- Visibility or width causes difficulty for pedestrians crossing the street
- Incomplete or inadequate sidewalk network
- Difficult to bicycle on the street
- Lack of lighting raises nighttime safety concerns
- Transit stops are inadequate
- Truck traffic is excessive

Some of these conditions are created by "conventional" street design, others have deeper roots. Currently, some roadway designs say "It's OK to go fast" and a design for higher speeds allows drivers to feel comfortable with their "ownership" of the road but causes other users to feel far less comfortable. The highest expression of this approach is the interstate highway. It uses access controls, clear zones, large curve radii, acceleration and deceleration lanes, large message signs, and other design features to isolate the road, ease driver decision-making, and make it safe and forgiving for the highest speeds. Interstates are targeted towards safety and mobility and are well-designed for these two goals. Local streets, on the other hand, require a completely different set of design considerations: access is paramount, there is no room for clear zones, curve radii are small, acceleration and deceleration lanes are less needed, and signage is scaled down. But, above all, the local street cannot be isolated for the safety of the high speed driver; it must be shared with pedestrians, bicycles, parked cars, delivery trucks, advertising signs, drainage

structures, and every other use made of our main streets. This basic condition shapes the visual and physical character of every local road and nearly all concerns stem from it. Some deeply rooted community concerns stem from roads and traffic but are more often expressions of traditional conflicts in American society. A very basic one is the issue of life safety and mobility versus livability. For example, the director of a nursing home wants to place furniture in a hallway so that the residents can sit and talk, but the fire safety director doesn't want any furniture in the hall because it's a fire hazard. This dilemma springs from differing goals. In Main Street projects, it often takes the form of one group desiring narrow streets and large sidewalks while the fire department insists upon wide streets for mobility and easy access to all structures.

Another is the issue of self-expression versus community values. The business community's desire for parking at the front door, easy access by private automobile, and control of its "turf" or business environment often clashes with the larger community's desire for alternate modes of transportation, less asphalt, and more opportunities for personal communication and beauty. One form the discussion takes on a main street is delivery trucks. Should deliveries be allowed at any time for the convenience of the shipper and the store owner but to the detriment of traffic flow? Or should delivery hours or locations be restricted to the inconvenience of businesses but the benefit of traffic? Whose values should prevail? Still another basic issue is the notion of current desires versus long-term needs. Should the crosswalk be a painted white stripe or stamped concrete? Should the no parking area be designated by a sign or some other technique? Are street trees worth the possible later costs of repairing root damage to sidewalks and sewer lines? This question is the age-old one of balancing the function of the improvement with the form of the improvement.

The last common conflict is tradition versus change. This is the familiar debate about the virtues of the countryside versus the values of the city. It takes many forms along a main street and is reflected in arguments over the "city" solution of a traffic signal when the "old" four-way stop has been working well for fifty years. The same may be said for the "new" ideas of pedestrian nodes or bumpouts, median planters, or narrowed lanes.

There are no technical answers to any of these conflicts. The only avenue to their resolution is building awareness and better perceptions among those trying to address them. The most important questions that arise are not matters of expertise. The challenge is to establish values and priorities and to decide which approaches are legitimate and which are not; in other words, to define the framework and terms of reference within which experts should work. This is a problem for the community, not for the experts themselves. To solve the problem, community members must achieve a better knowledge of those things which form the community environment and how those things are interconnected. This is achieved by going out into the community and talking about what is possible. The key approach is "Our community would function so much better if . . ."

Achieving even the single objective of reducing vehicle speed will require the use of a variety of physical solutions. Achieving the additional objectives of reducing the volume

of traffic, improving the appearance of the street, improving pedestrian accessibility, and reducing auto dependence will require even more changes to the roadway.

15-1.2 But Keep In Mind …

KNOW THE ROOT CAUSE OF THE PROBLEMS
Before applying solutions always identify the problems and their root cause. Sometimes the problems are a result of land use issues. Without the local community resolving the land use issues, through their home rule authority, any transportation solution will just be a bandaid. Realize that flexibility is a two-way street. Match the community's responsiveness with design flexibility.

ANALYZING THE IMPLICATIONS
Remember that improvements are not really improvements if they shift the problem to the next block, make it difficult for businesses to receive goods or customers, or complicate the provision of emergency services. All of the ideas for improvement must be tested. If the solution takes care of the immediate area but creates a problem elsewhere, it is time to rethink the answer.

BICYCLE NEEDS
Bicyclists are becoming a vocal force in the design of roadways and many communities are seeking to support increased levels of bicycle use. Bicycle racks, secure storage, wider travel lanes, separate paths, and safe crossing points are all items that may surface in a local project. MaineDOT's policy is to consider bicycles on all roadway improvement projects and to address bicycle needs where it is reasonable and feasible to do so. Contact the MaineDOT Bike/Pedestrian Coordinator in the Office of Passenger Transportation, 16 State House Sta, Augusta, Maine 04333 for assistance with Bike facilities.

LOCAL ACCESS
Parking and access for businesses, access for delivery vehicles, snow removal, individual driveways, responsibility for sidewalk maintenance, the location of mailboxes, and dozens of other large and small "access" concerns will arise in the course of the project. There are no standard solutions that will apply in every case, there are only examples of how other communities have dealt with the issues and their experience over time with the results. New access points to highways, not in the urban compact, need to be permitted through the appropriate Regional Engineer. For a copy of the rules go to this web address: ftp://ftp.state.me.us/pub/sos/cec/rcn/apa/17/229/229c299.doc

LARGE VEHICLES
Because trucks, buses, and many emergency vehicles have large turning radii, care must be taken when reducing curb radii or installing median islands or roundabouts. If the lane widths or turning movements are too restricted, access could be denied to large vehicles. Unless restricted access is the purpose, all turning radii and lane widths should be checked for their ability to accommodate the necessary vehicles. This can be done on the plan drawings with a "turning template" or in the field with a temporarily marked roadway and actual vehicles.

ENFORCEMENT
A carefully designed road should reduce traffic enforcement needs by maintaining speed limits, clearly identifying parking options, and improving the basic level of safety for pedestrians. A poorly conceived plan could create opportunities for higher speeds, "blind spots" such as fences or shrubs that are difficult for enforcement officials to see behind or gain access to, and confusing parking or access patterns for the local resident. All designs should be studied from a common sense perspective and with the assistance of local public safety officials.

MAINTENANCE
Care and maintenance must be built into the design by thinking about types of materials, longevity, ease of maintenance, life cycle costs, local maintenance capabilities, etc. The aim is to ensure that project character is not altered by future "fixes" such as roadway signs, utility upgrades, tree trimming, or maintenance failures. To preserve the design intent of the project from later changes, the following items must be considered from the beginning.

- Material life
- Access
- Equipment needed
- Replacement cost
- Trash removal
- Landscape care and replacement
- Safety and lighting of spaces
- Coordination with public utilities

TRAFFIC CALMING
The term "traffic calming" is an important component of many highway projects in Maine, especially in communities struggling to 'calm' or slow traffic through their historic villages.

Equally important in this approach to transportation planning are the compatible goals of restoring aesthetic qualities and improving pedestrian safety in village centers. Proven traffic calming methods employed in the streetscape design also plays an important role in traffic calming with enhancements such as lighting, signage and landscaping, which reinforce village character and at the same time, improve aesthetics and human comfort.

Taken together, these initiatives enhance the historic attributes and pedestrian scale of the village and help to keep it a vibrant, satisfying place to live and work, as well as to visit. See the MaineDOT Traffic Calming Policy, Appendix 15-B

TORT LIABILITY

Tort Liability is a real concern for many highway engineers. As a result of concerns about litigation, designers may be tempted to be very conservative in their approaches to highway design and avoid innovative and creative approaches to design problems. The best defense for a design engineer is to present persuasive evidence that the guidelines were not applicable to the circumstances of the project or that the guidelines could not be reasonably met. Designers need to remember that their skills, experience and judgment are still valuable tools that should be applied to solving design problems and that, with reliance on complete and sound documentation, **tort liability concerns need not be an impediment to achieving good road design.**

15-1.3 References

This Report Uses References From:

- A Policy on Geometric Design of Highways and Streets, American Association of State Highway Transportation Officials, 2004 (a.k.a. AASHTO Green Book)
- MaineDOT Highway Design Guide, Volume One, National Standards, December 2004
- MaineDOT Highway Design Guide, Volume Two, State Standards, July 2003
- Roadside Design Guide, AASHTO, 2002
- A Guide to Achieving Flexibility in Highway design, AASHTO, May 2004
- Flexibility in Highway Design, U.S. Dept of Transportation
- Highway Capacity Manual, Transportation Research Board

15-2 FLEXIBILITY IN HIGHWAY DESIGN

Contents of Design Tips

Design Features **Page**

LANE AND SHOULDER WIDTH

DESIGN FEATURE	SOLUTION	REFERENCE
Lane widths of 12ft are desirable on both urban and rural facilities	The use of 11ft lanes are acceptable in urban areas where right-of-way and existing development become stringent controls. Lanes 10ft wide are acceptable on low-speed facilities. Lanes 9ft wide are appropriate on low-volume roads in rural and residential areas.	AASHTO Green Book Pg. 312 Low-volume roads typically have an ADT<400
Lane widths are related to the traffic demands and design speeds. A traveled way width of 24ft is required for arterials with an ADT of 400-1500 and a design speed of 60mph or greater, an ADT of 1500-2000 and a design speed of 55mph or greater, and a DHV over 200 and a design speed of 35mph or greater.	Width of traveled way may remain at 22ft on reconstructed highways where alinement and safety record are satisfactory. Off system highways use State Standard widths.	AASHTO Green Book, Pg. 448 Maine Highway Design Guide, Volume Two.
The width of the shoulder on an added lane should match that of the adjoining two-lane highway.	The width of the abutting shoulder should be a minimum of 4ft wide.	AASHTO Green Book, Pg. 247. MaineDOT Highway Design Guide, Volume One

VERTICAL CLEARANCE

New or reconstructed structures on freeways and arterial systems should provide 16ft clearance over the entire roadway width.	Existing structures can be retained that provide 14.5ft, if allowed by local statute. In highly urbanized areas, a minimum clearance of 14ft may be provided if there is one route with 16ft clearance. Structures should provide additional clearance for future resurfacing of the underpassing road.	AASHTO Green Book, Pg. 447 & 472
The desirable clear height of all grade separation structures above traveled way and shoulders should be 16.5ft. Most states permit the vehicle height, including load, to be between 13.5ft and 14.5ft. Maine permits a vehicle height of 14ft. The clear height of all structures above traveled way and shoulders should be at least 1ft greater than the legal height. Allowance should be made for future resurfacing, for snow or ice accumulation and for occasional slightly over height vehicle.	The recommended minimum clear height of all structures above traveled way and shoulders is 14.5ft.	AASHTO Green Book Pg. 763

HORIZONTAL CLEARANCE

DESIGN FEATURE	SOLUTION	REFERENCE
On urban arterial street sections, a 3ft clearance from curb to face of object is desirable to provide the clearance required for overhang of trucks from striking the object.	Clearance from curb to face of object of 1ft (or wider where possible) should be the minimum.	AASHTO Green Book Pg. 437, 448 & 481

Physical obstructions in or near the roadway should be removed in order to provide the appropriate clear zone.	Where removal is impractical, such objects should be adequately marked by painting or by use of other high-visibility material.	AASHTO Green Book Pg. 295
For a certain design speed and fill slope, there is a recommended clear zone distance.	In one example, the trapezoidal channel design does not conform to recommended gradual slope changes and the recommended clear zone distance is not met. However, if the channel bottom and backslope are free of obstacles, no additional improvement is suggested.	AASHTO Roadside Design Guide, Pg. 3-11
Variable clear zone distances are based on traffic volumes, speeds and roadside geometry.	Clear zones may be limited to 30ft for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.	AASHTO Roadside Design Guide, Pg. 3-1 & 3-2

CROSS-SECTIONAL ELEMENTS

DESIGN FEATURE	SOLUTION	REFERENCE
Roadways need to be built to the standards for the various functional classifications.	If sufficient right-of-way is not available, reconsider the functional classification, consider lowering the design speed, consider building a 3R project, or request a design exception.*	FHWA publication "Flexibility in Highway Design", Pg. 97
The appropriate number of travel lanes for the level of service desired can be determined using the procedures in the Highway Capacity Manual knowing future projected travel demands.	A community may decide through public involvement that a lower level of service than normally provided is acceptable.	FHWA publication "Flexibility in Highway Design", Pg. 76.

Barriers are needed to minimize the severity of potential accidents involving vehicles leaving the travel way where the consequences of errant vehicles striking a barrier are less than leaving the roadway.	Weathering steel is a low cost option for designers who are trying to "blend" a barrier into the surrounding environment.	FHWA publication "Flexibility in Highway Design", Pg. 94.

HORIZONTAL AND VERTICAL ALINEMENT

DESIGN FEATURE	SOLUTION	REFERENCE
Impact to the surrounding environment should be minimized as much as possible during construction and reconstruction.	Careful attention to detail during the route location and preliminary design phase can minimize the impact on the surrounding environment for example, minor adjustments on one project eliminated the need to acquire any of the adjacent homes and businesses	FHWA publication "Flexibility in Highway Design", Pg. 68.
Efforts should be made to avoid impacting historic districts.	Consider the use of "cut-and-cover" design.	FHWA publication "Flexibility in Highway Design", Pg. 69.
There should be coordination of horizontal and vertical alignment.	Ensure the most effective coordination through the use of multidisciplinary design teams.	FHWA publication "Flexibility in Highway Design", Pg. 71.
Horizontal and vertical geometry's should be designed concurrently as they must be complimentary.	One tool is to use computer-aided design (CAD).	FHWA publication "Flexibility in Highway Design", Pg. 67.

DESIGN SPEED

DESIGN FEATURE	SOLUTION	REFERENCE
Above-minimum design values should be used where feasible, but in view of the numerous constraints often encountered, practical values should be recognized and used.	Develop project under 3R design criteria by adjusting scope of project. Off system roadways use State Standards. Use the design exception process. (App 15-A)	AASHTO Green Book Pg. 68-72. FHWA pubulication "Flexibility in Highway Design", Pg 32-33.

	Look at lowering the posted speed.	MaineDOT Highway Design Guide, Volume One, Chapter 11. MaineDOT Highway Design Guide, Volume II.

LEVEL OF SERVICE

DESIGN FEATURE	SOLUTION	REFERENCE
While the Highway Capacity Manual provides the analytical basis for design calculations and decisions, judgment must be used in the selection of appropriate level of service for the facility under study.	Lesser rates may be used for certain recreational routes or for environmental or land use planning reasons.	Highway Capacity Manual. FHWA publication "Flexibility in Highway Design", Pg. 32-33 AASHTO Green Book Pg. 84

STOPPING SIGHT DISTANCE

DESIGN FEATURE	SOLUTION	REFERENCE
Minimum stopping sight distances are required for various design speeds.	It is permissible to utilize the lowest recommended stopping sight distance in the range of values provided. Consider lowering the design speed for an entire corridor. Use the design exception process. See App 15-A	AASHTO Green Book Pg. 112

SUPERELEVATION

DESIGN FEATURE	SOLUTION	REFERENCE
It is desirable to provide as much superelevation as practical. MaineDOT uses a maximum superelevation rate of 6% on rural roadways and 4% on urban.	Tables in the AASHTO Green Book Chapter III, and IX allows for a range of superelevation rates where a change in design speed or radius can reduce or increase the superelevation rate. Develop project under 3R design criteria by adjusting the scope.	AASHTO Green Book Pg. 132-163, 639-648.

ENTRANCES/DRIVEWAYS

DESIGN FEATURE	SOLUTION	REFERENCE
Directly related to the functional classification of the particular roadway, and whether it is residential or commercial.		

PARKING

DESIGN FEATURE	SOLUTION	REFERENCE
The effect of curb radii on the path of various design vehicles is directly related to the length of parking restrictions.	Consider three-centered curves or an offset simple curve in combination with tapers or spirals to fit the path of the vehicle.	AASHTO Green Book Pg. 593 – 609, Table IX-1, IX-2.

AUXILIARY LANES

DESIGN FEATURE	SOLUTION	REFERENCE
For at-grade intersections, auxiliary lanes desirably should equal that of the through lane.	Auxiliary lanes should be at least 10ft wide.	AASHTO Green Book Pg. 714.
	Auxiliary lane can be the same as, but not less then, the width of the travel lane	MaineDOT Highway Design Guide, Volume One

15-3 ADDITIONAL FEATURES TO CONSIDER:

The following sections, 15-3.1, 15-3.2 and 15-3.3, list project features that will have a major effect on traffic patterns of vehicles, bicycles and pedestrians as well as project cost. These features are identified in the early planning stages of a project when project scoping discussions are taking place between the Bureau of Planning staff and the Communities involved. Cost sharing of the various features is also determined at that stage based on relevance of the feature to the community or to the State. The identified features are listed in the Planning Report and in a community MOA when the project is handed off to the Program who will be the lead unit.

Sometimes these features are identified as important later in the project development stage. Because of the long term effects of these features as well as costs to the project and various cost sharing responsibilities, they should only be added to a project after discussions have taken place between the Program, Planning and the Communities involved.

15-3.1 Improving Pedestrian Accessibility

Sidewalks – Sidewalks are essential in commercial and residential areas. Even with low vehicle speeds, children, seniors, and people with disabilities cannot walk safely without sidewalks. The Americans with Disabilities Act provides the basic standards for minimum width and accessibility. Items to remember are that two people should be able to walk side-by-side: sidewalks that aren't separated from vehicle travel lanes by green strips (or parked cars) should be wider than the standard: and sidewalks next to fences, walls, or buildings should be wider than the standard.

Curb Ramps – These provide a smooth and gradual transition between the sidewalk and the road surface and are designed for access for wheelchairs, walkers, and strollers. The Americans with Disabilities Act provides standards for their location and design including truncated domes to warn pedestrians that they are about to step into approaching traffic.

Marked Crosswalks – Marked crosswalks alert drivers that they are approaching an area of pedestrian activity and alert pedestrians to a safe and accessible crossing. The idea is to incorporate a textured or patterned surface which contrasts with the surrounding roadway. Crosswalks can be marked with stripes, colored concrete or pavers, or stamped asphalt. A crosswalk with texture also serves to slow drivers because of its roughness and noise. Mid-block, as opposed to intersection, crosswalks may be difficult to justify unless accompanied by flashing lights or signs. Another way of making crosswalks more noticeable are embedded lights such as were used in Brunswick on Maine Street. Bump-outs can be used to reduce the length of crosswalks. See Appendix 15-C, Guidelines for Crosswalks for more information.

15-3.2 Features Outside of the Curbs

Features outside the curb need to be located outside of the clear zone so that they are not a danger to vehicular traffic.

For urban arterials, collectors and local streets where curbs are utilized, space for clear zones is generally restricted. A minimum offset distance of 18 inches should be provided beyond the face of the curb, with wider offsets provided where practical. This “operational” offset will generally permit curbside parking and will not have a negative impact on traffic flow. However, since most curbs do not have a significant capacity to redirect vehicles, a minimum clear zone distance commensurate with prevailing traffic volumes and vehicle speeds should be provided where practical.

For clear zone offsets for rural or non-curbed highways see pages 10-7 in Volume I and B-9,10 in Volume II of the MaineDOT Highway Design Guide.

Identification Signs – Non-traffic signs that welcome visitors to a community or district help establish identity and communicate a pride of place. They do not have to be large but within each community should be of a consistent shape, color, and material if more than one is used.

Planters and Banners – Sidewalk planters, hanging planter baskets, and pole banners are an excellent way to add color to the street, divert attention from overhead utilities, identify a special district, or advertise events. Care must be taken not to interfere with pedestrian movement along the sidewalk or add safety distractions for drivers.

Street Furniture – Benches, waste containers, planters, bollards, pedestrian lighting, and kiosks all help create a walkable street environment by “announcing” to the public that they are welcome and their needs have been considered. A number of historic and contemporary styles of benches are available for consideration, including such styles of metal, wood and granite. These amenities should be high-quality, durable, attractive, easily maintained, and placed in such a way that a harmonious design theme is apparent and adjacent structures are complimented.

Landscaping – Most images of healthy communities include treelined streets interspersed with grass and shrubbery. This holds true in commercial as well as residential areas. Apart from their physical beauty, these landscaped areas create a friendly, walkable environment by separating pedestrians from cars and slowing driver speeds. The space required for vegetation varies with the type selected; grass or shrubs will require less room than a deciduous tree. Selecting the proper vegetation is critical – all vegetation should be appropriate for the specific climate where it is to be planted, low maintenance, placed to not uproot curbs or walks, located out of essential sight lines, and selected to not interfere with overhead utility lines.

Gateways - 'Gateways' with signage, landscaping, granite posts and sidewalk markers can alert motorists that they are entering into a village center and should adjust their driving styles accordingly.

Lighting - New, energy efficient, village-scaled lighting fixtures can be used in the village center. New lighting design and engineering of the lighting levels and coverage will result in safer and more consistent illumination than may presently exist. New or existing sidewalks can be sufficiently lit and ensure that pedestrians and schoolchildren will have adequate lighting levels during the dark afternoons of winter and on summer evenings as well.

Lower pole heights (12-14 feet) and softer illumination controlled by either timers or photocells can be provided, and higher poles (16-18 feet) and brighter illumination levels are for locations adjacent to the highway and new sidewalks. As an added benefit, electrical outlets can be installed in the poles around the downtown, facilitating the use of power for special events.

15-3.3 Features Between the Curbs

Bike Lane – This is a portion of the roadway designated by pavement markings and signing for exclusive use by bicycles. A bike lane for one-way movement should be at least five feet wide. A bike lane for two-way traffic should be at least eight feet wide and separated from the vehicle lane with a barrier such as a curb or island. Bike lanes are best provided if the street is commonly used by bicyclists or if it links important bike destinations.

Narrowed Lanes – This is simply a reduction in the width of the travel lane. It is used to reduce vehicle speeds, reduce the crossing distance for pedestrians, increase pedestrian visibility, and to prevent parking too close to an intersection. Typically, low volume streets (i.e. one car or less per minute) do not need wide travel lanes.

Chicanes – A chicane is a series of curb bump-outs or nodes that extend out into the street on alternating sides of the roadway. They may or may not narrow the travel lane but always require the driver to steer from one side of the roadway to the other to negotiate the chicane. They slow traffic, discourage shortcutting, and provide landscaping opportunities.

On-Street Parking – Parking can be allowed on both sides of a roadway or parking zones can be located on alternating sides of a street to create a chicane effect. Both alternatives may reduce vehicle speeds because of "side friction" and potentially reduce the volume of through traffic along a street. Because this measure relies on an effective reduction in traffic lane width for much of its effect, the provision of additional space for bicycles would reduce effectiveness significantly. If streets are wide enough, angled parking increases the total number of parking spaces that can fit within a block and often lowers speeds because the travel lane width is slightly narrowed and drivers are more alert to cars backing into the roadway.

Choker – A set of two curb bump-outs or nodes that extend into the street at an intersection narrowing it to as small as one lane. It causes drivers to slow when entering and exiting the street. The choker is used when there is an unacceptable amount of shortcut traffic, speeding, or a transition is needed from a street in a business area to a street in a residential area.

Bumpouts or Nodes – These features extend the sidewalk into the street. They provide opportunities for landscaping and street furniture, shorten the street crossing distance for pedestrians, protect parked cars from on-coming traffic, and provide better visibility for pedestrians by allowing them to look around parked cars without entering the street. Bumpouts at an intersection prevent parking in a crosswalk or blocking handicapped ramps. They also slow traffic by narrowing the roadway and restricting turning speeds.

Curb Radius Reduction – Reducing the radius of a curb at an intersection can slow drivers who do not completely stop to make a right turn. A reduced radius shortens the pedestrian crossing distance, improves visibility, reduces turning speeds, and may add parking spaces. Always consider the turning radii of trucks, buses, and emergency vehicles when they are heavy users of the intersection.

Full Street Closure – This is a physical barrier that closes the street to vehicles. Pedestrians, bicycles, wheelchairs, and emergency vehicles can be accommodated. A turnaround should be provided at the closure. Use of a full street closure is highly unlikely on a state road, but may be desirable on connecting neighborhood streets if they are used as shortcuts and cause high traffic volumes and pedestrian conflicts.

One-Way Streets – Designating a street for one-way traffic can be used to improve mobility or restrict vehicle access. A one-way street should be paired with another street with traffic flow in the opposite direction and is best used on narrow streets with high volumes where the one-way prohibition is self-enforcing. One-way streets can result in higher speeds and, if not carefully planned, increase traffic through other areas as drivers seek alternate routes.

Partial Street Closure – This is created by a node or curb extension that physically blocks one direction of traffic at an intersection on an otherwise two-way street. It is the equivalent of a Do Not Enter sign but provides landscaping space and a physical barrier. It is used to eliminate cut through traffic.

Pedestrian Refuge Islands – Pedestrian refuges are raised islands in the center of the street at marked, intersection crosswalks. They allow pedestrians faced with a wide street and a short signal sequence, a chance to stop safely before crossing the rest of the street. They also provide an opportunity for landscaping.

Raised Intersections – This measure raises the surface of the roadway from crosswalk to crosswalk as a means of reducing speeds and better defining crosswalk areas. Although they are not used on arterial highways, they can be looked at for use on collector or local streets.

Roundabouts – These are large, raised islands, usually landscaped, designed to lower speeds and improve traffic flow as drivers maneuver through an intersection. Traffic circulates in one direction only and no signals are used. Roundabouts differ from Rotaries in that vehicle speed is greatly reduced as well as vehicle lane weaving.

Traffic Signs – Stop, yield, speed limit, and warning signs require that very specific conditions be present to warrant them. Posting too many can cause unnecessary distractions or cause drivers to disregard the sign's warning.

Speed Humps – These are raised areas of pavement extending completely across the roadway that deflect both the wheels and the frame of a crossing vehicle. They are designed to reduce speeds with the desired speed controlled by the dimensions of the hump and the spacing between them. Although they are not used on arterial highways, they can be looked at for use on collector or local streets.

Medians – These are long, raised islands placed in the center of the roadway. They slow traffic, provide space for landscaping, and give pedestrians a safe place to stop as they cross the street. Placing a median in an existing street typically requires narrowing lane widths, eliminating a travel lane(s) or removing parking. Medians can be especially effective on four-lane roads where they dramatically improve the visual quality of the facility. They limit access to properties by stopping left turn movements and they are a good tool in the right context.

Interrupted Sight Lines – If drivers can see a long way into the distance, their speed increases; if they cannot see a long way ahead, their speed decreases. In certain low speed conditions, interrupting a driver's sight line with chicanes, roundabouts, bumpouts, medians, or crosswalks not only maintains slow speeds but widens a driver's vision so for the shorter distance they are more aware of pedestrians and cyclists.

APPENDIX 15-A

The Design Exception Process

Despite the range of flexibility that exists with respect to virtually all the major road design features, there are situations in which the application of even the minimum criteria would result in unacceptable high costs or major impact on the adjacent environment. For such instances when it is appropriate, the design exception process allows for the use of criteria lower than those specified as minimum acceptable values in the Green Book.

If the Highway project is not on the NHS, the State does not need the FHWA approval for a design exception.

(MaineDOT policy states, approval for design exceptions of the controlling State Standards for off system must come from the Director, Bureau of Project Development.)

For projects on NHS routes, FHWA requires that all exceptions from accepted guidelines and policies on the 13 specific controlling criteria be justified and documented in a manner as stated in FHWA memorandum at http://www.fhwa.dot.gov/legsregs/directives/fapg/0625sup.htm.

The 13 specific controlling criteria are:

1. Design speed
2. Lane width
3. Shoulder width
4. Bridge width
5. Structural capacity
6. Horizontal alinement
7. Vertical alinement
8. Grade
9. Stopping sight distance
10. Cross Slope
11. Superelevation
12. Vertical clearance
13. Horizontal clearance (not including clear zone)

The design exception should be documented and accepted by the Preliminary Design Report (PDR) stage of the MDOT project development process.

APPENDIX 15-B

MAINE DEPARTMENT OF TRANSPORTATION
TRAFFIC CALMING POLICY:

The purpose of this policy is to provide guidance to local, regional and State jurisdictions for the application of traffic calming techniques on streets and highways having a Federal functional classification of principle arterial, minor arterial or major collector. Maine's arterial and major collector systems provide a network for the safe and efficient inter-regional movement of people, goods and services between and through major urban centers. Mobility is the prime function of these higher classifications.

Concerns have been raised about the compatibility of traffic calming objectives with the prime mobility function of arterial highways and streets.

For policy purposes, MaineDOT will use the following definition of traffic calming established by the Institute of Transportation Engineers:

> *"Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non motorized street users."*

Traffic calming treatments cover a range of categories and features as indicated in Table 1.

MaineDOT believes that traffic calming, as defined by the Institute of Transportation Engineers, is a valid and useful approach to traffic management on rural highways that are Federally functionally classified as local streets and minor collectors, and on urban roadways classified as local streets and collectors. Consequently, the full range of traffic calming techniques may be considered appropriate for implementation on highways bearing these Federal functional classifications.

Given the fact that the prime function of the higher classifications of arterial highways and streets is to provide mobility for transportation systems users, and given the fact that the objectives of certain traffic calming techniques are incompatible with the mobility function of arterials, MDOT will prohibit vertical changes involving speed humps, speed bumps, or raised intersections, and lateral changes involving chicanes, offset intersections, or lateral shifts in the geometric alignment of highways and streets that are Federally functionally classified within the urban compact areas as arterials. In the rural areas, the restriction prohibiting geometric changes identified above will apply to highways that are Federally functionally classified as major collectors and arterials or any road posted for speeds 45 miles-per-hour and above.

Table 1 displays the effects of this policy on the range of traffic calming categories by Federal functional classification.

Category	***Features***	***Federal Functional Classification***
Vertical changes in street	Speed humps, speed bumps, raised intersections.	Not permitted on arterials within the urban compact. Not permitted on arterials, major collectors or any road posted for speeds 45 mph and above in the rural areas.
Lateral changes in street	Chicanes, offset intersections, lateral shifts.	Not permitted on arterials within the urban compact. Not permitted on arterials, major collectors or any road posted for speeds 45 mph and above in the rural areas.
Constrictions	Narrowings, neckdowns, pinch points, islands.	Eligible treatment for all classifications, determined by the design process.
Narrow pavement widths	Medians, edge treatments.	Eligible treatment for all classifications, determined by the design process.
Entrance features		Eligible treatment for all classifications, determined by the design process.
Circular intersections	Roundabouts, traffic circles.	Eligible treatment for all classifications, determined by the design process.
Small corner radii		Eligible treatment for all classifications, determined by the design process.
Related streetscaping	Surface textures and colors, landscaping, street trees and furniture.	Eligible treatment for all classifications, determined by the design process.

Table 1

Other traffic calming techniques that do not involve the top two categories in the table above may be considered as part of an overall traffic management plan for arterials and major collectors in both the urban compact and rural areas.

POLICY ADDENDUM: Potential exceptions. The Department recognizes that some jurisdictions may feel that an exception to this policy may be justified in certain locations or under special/unique circumstances. Whenever a request is made to the Department for an exception to this policy, four basic levels of traffic management need to be considered and addressed.

Level 1: Establishing (or revising) and enforcing general laws and ordinances pertaining to speed limits, intersection controls, and parking regulations. This strategy should generally be the first used to attempt to address evolving neighborhood concerns.

Level 2: Educating residents to better understand the causes of traffic problems, potential solutions to those problems, and the advantages/disadvantages of implementing various solutions. This strategy should be pursued anytime neighborhood concerns are addressed.

Level 3: Installing traffic control devices that provide specific regulatory, warning, or guide messages to motorists. These should be used judiciously and in conformance with the Manual on Uniform Traffic Control Devices.

Level 4: Installing geometric design features that manage the physical movement of vehicles or pedestrians within the roadway or within a neighborhood. These should be used as a remedial technique **only when the above methods have proved ineffective.**

The Department requires that some level of documentation detailing the efficacy of the steps be submitted before consideration can be given to an exception to the policy.

Also the Department requires that any local or regional jurisdiction that is considering traffic calming within their community or region develop a municipality wide or regionally based traffic calming plan that documents the needs and specifies the areas where traffic calming may be appropriate to address the needs of the community. This municipal/regional plan shall be reviewed and approved by the responsible municipal/regional authority and the Department. Possible exceptions to the policy on arterial traffic calming should be identified in these plans and reviewed on a case-by-case basis for the purposes of identifying the most appropriate treatment to solve the problem. Any proposed treatments must minimize potential conflicts between the objectives of traffic calming and the mobility function of roadways.

A good reference for traffic calming is located at http://www.ite.org/traffic/tcstate.htm. This website includes "Traffic Calming: State of the Practice, ITE/FHWA, August 1999".

APPENDIX 15-C

<u>State of Maine</u>
Guidelines for Crosswalks

Crosswalks are marked areas where pedestrians can safely cross a roadway. By law in the State of Maine (Title 29-A Subsection 2056,4) any vehicle must yield the right-of-way to a pedestrian who has entered a crosswalk when a traffic control device is not in operation. This law makes it imperative that crosswalk placement, painting and usage be done in a uniform way.

1. All crosswalks shall meet the latest Manual on Uniform Traffic Control Devices (MUTCD) standards. They shall be a minimum of six (6) feet wide and marked with white paint as shown on the attached sheet. Crosswalks shall be painted at least annually and shall be retroreflective for nighttime visibility. Crosswalks should be lighted for nighttime use.

2. All crosswalks shall meet the criteria put forth in the American's with Disabilities Act (ADA).

3. All crosswalks should extend from one safe landing zone to another. A safe landing zone is an area where a pedestrian is safe from vehicle conflict while waiting to cross or when finished crossing. Islands, walkways and sidewalks are typically considered safe landing zones, while road shoulders, driveways (under normal circumstances) and parking areas are not considered safe landing zones. Provisions should be made for winter maintenance of the landing zones, including but not limited to snow and ice removal.

4. Crosswalks shall, to the maximum extent practical, be perpendicular to the highway. No crosswalks shall be constructed more than 30 degrees from perpendicular.

5. Crosswalks shall be installed in areas where the speed limit is 35 mph or less.

6. Crosswalks shall be placed in areas where there is sufficient stopping sight distance for the posted speed limit as set forth in Table 1. Stopping sight distance for the purpose of evaluating a crosswalk shall be measured from a 3.5 foot driver eye height to a 3.5 foot pedestrian height.

Table 1 – Sight Distance

Posted Speed (MPH)	Sight Distance (Feet)
20	155
25	200
30	250
35	305

7. Crosswalks shall have the appropriate signage (W11-2 series from the Manual on Uniform Traffic Control Devices, see attached sheet). These signs shall be black symbol on yellow background or black symbol on fluorescent yellow-green background. Sign colors should not be mixed in any area.

8. Crosswalks should be located a minimum distance of 500 feet apart.

9. No parking shall be allowed within 20 feet of any unsignalized crosswalk and 30 feet at a signalized intersection. Signs should be installed indicating that no parking is allowed.

10. Crosswalks in school zones should have crossing guards for times when school is starting and ending. School crosswalks should be at roadway intersections. Mid-block crossing should only be used when a high concentration of students will be using them, as driver expectation is not to have to stop at a mid-block location.

11. If a municipality proposes a crosswalk on a roadway with more than 1 lane in any direction, they would need to submit a traffic engineering study indicating that the location of the crosswalk would be safe. Placement of such crosswalks shall require approval by the State Traffic Engineer or his/her designee.

12. Prior to installing crosswalks, on State roads or State aid roads towns shall enact traffic ordinances dealing with crosswalks. At a minimum, Items 1 through 11 should be included. Municipalities are entitled to place crosswalks if they are in accordance with these guidelines. If a municipality wants a crosswalk other than as defined in these guidelines, they would need to submit a traffic study indicating that the location of the crosswalk would be safe. Placement of crosswalks other than as specified shall require approval by the State Traffic Engineer or his/her designee.

BASIC HIGHWAY DESIGN CHECKLIST

Revised December 2004

RESOURCES

- ⇨ MDOT Highway Design Guide
- ⇨ Maine Department of Transportation Standard Specification Book
- ⇨ Department of Transportation Standard Details
- ⇨ AASHTO - A Policy On Geometric Design of Highways and streets
- ⇨ Project Development Process Guide
- ⇨ MDOT mx manual
- ⇨ MDOT Best Management Practices for Erosion and Sediment Control
- ⇨ MDOT State Standards Highway Design Guide
- ⇨ Highway Improvement Program Report
- ⇨ AASHTO Design Procedures for New Pavements
- ⇨ AASHTO Roadside Design Guide
- ⇨ MDOT dictionary

This Basic Highway Design Checklist…..

⇨ ***Is intended*** as a supplement to the Highway Design Guide and should not be used in place of it.

⇨ ***Is Not exhaustive***

⇨ ***Is a general progression - every project is different*** - individual judgments and preferences should be exercised within limits allowed by department policies and standards. Some design steps occur in parallel with others and a true linear progression for design really doesn't exist.

⇨ ***Is Checklist tool*** to help guide the design process

Suggestions for improvements to this checklist are welcome and appreciated!!!

<u>BASIC HIGHWAY DESIGN CHECKLIST</u>

Revised December 2004

INITIAL TEAM MEETING MILESTONE

Collect and Assemble project information

(This occurs throughout the design process - some information is needed at the beginning stages in order to determine the proper standards to use and the project scope.)

__ Highway classification
__ Aran / FWD request if necessary
__ Crash data
__ Traffic data - current year and design year
__ Posted Speed
__ Planning report
__ Project history - correspondence
__ Old plans from vault
__ Aran video - tape #
__ Geotechnical information and recommendations from geotechnical team member
__ Hydrological information
__ Projex reports
__ TIDE / TINIS reports - posted speeds / exist. Road widths / roadway history
__ Request Survey - Plot survey -Is additional survey needed?
__ If CRF is greater than 1 seek traffic evaluation and recommendation
__ If necessary, request intersection turning movements and counts
__ Wetlands information (*Environmental and Survey team members*)
__ Historic issues / impacts (4f document) (*Environmental team member*)
__ Contaminated soil information (*Environmental team member*)
__ Existing R/W widths
__ Utilities involved on the project
__ Aerial Photography

BASIC HIGHWAY DESIGN CHECKLIST

Revised December 2004

Determine project scope - analyze the existing road see scope process in the Highway Improvement Program Report January 1997 - figure 1

__ Site review - how does the road ride?
__ Team meeting (*preferably on site*)
__ Check accident data - safety concerns
__ Check sufficiency of the existing horizontal alignment - does it meet current AASHTO standards?
    Minimum radius
    Lateral clearance -middle ordinate SSD

Use old plans or create new alignment matching the existing roadway as

__ Check existing vertical alignment - does it meet current AASHTO standards?
    SSD / HLSD
    Maximum grades

Plot existing ground profile (longsection) and use marked up triangles to do a rough check of

__ Existing Cross slopes and superelevations - are they up to standard?
__ Year built
__ Correspondence with towns - if any - check project file
__ Is it a bike route - check with the bikeways coordinator in Planning
__ Pavement condition
    Pavement management recommendation - if available
    Visual inspection (*look for degree and type of cracking and rutting*)
    FWD
    Soils data

SCOPE

Safety Issues
Pavement / Soils
Drainage
Right of Way
O.E.S.-wetlands
Money

__ Obtain Geotech recommendations
__ Is road way structurally sound?
__ Are there drainage problems?
__ ROW issues - amount of existing ROW - discuss with ROW team member
__ O.E.S. issues *(wetlands/contaminated soils / sensitive water bodies etc.)* - discuss with Environmental team member
__ Seek traffic recommendation-if needed because of:
- crash history (CRF greater than 1)
- high traffic volumes
- town requests
- intersection complications

__ Truck lane warrants
__ Signal warrants - check with traffic team member
__ Does the town want new sidewalks?

BASIC HIGHWAY DESIGN CHECKLIST

Revised December 2004

Determine Design standards to be used

- AADT
- Posted Speed
- Design Speed - *a controlling design criterion*
- Project Scope-*New construction/Reconstruction/Rehabilitation / Overlay / 3R / 4R / State*
- Functional Class (Check Projex on computer and planning report for designation)
  Rural - Freeway / Arterial / Collector / Local
  Urban - Freeway / Arterial / Collector / Local
- NHS or non-NHS
- All projects need to be context sensitive

Consider the controlling criteria for the roadway

See chapter 3 in the Highway Design Guide for a list of controlling criteria
(*Design exceptions are required if controlling criteria cannot be met*)

Typical Section Design

- Determine travel lane width - see standards in Highway Design Guide and State Standards Design Guide - *a controlling criterion*
- Determine shoulder width - *a controlling criterion (Usually determined by aadt/roadway classification and project scope)*
- Pavement Cross Slopes (*Travel lane and shoulder*) - *travel lane cross slope is a controlling criterion*
- Darwin Pavement Design - depending on the type of project such as reclaim doing the pavement design early will allow for setting the proper vertical alignment
  - Check existing soils conditions - geotech
  - Existing gravel depth - soils explorations from geotechnical team member and or old plans from vault
  - Traffic data to determine esals (18 kip value x design year x 365 days/year = esals)
  - Use FWD data to determine resilient modulous - see geotechnical team member
  - Run Darwin pavement design to obtain pavement thickness
  - Check numbers - It would be a good idea to run the results by another experienced designer

Create Roadway Design

Horizontal Alignment - if not already created (see chapter 5 in the Highway Design Guide)

- Check minimum radius - *a controlling design criterion.*
- Check lateral clearance for the SSD - *a controlling design criterion.*
- Obtain alignments of recently built abutting projects from survey in order to match new alignment properly
- Avoid broken back curves - (*An excessively short tangent that does not allow for a proper superelevation transition between curves*)

- Determine correct superelevation rate for curves

- Review alignments with another experienced designer

Vertical Alignment (see chapter 4 in the Highway Design Guide)

- On large earthworks projects try to balance cut and fill quantities
- Maximum grades are a controlling criteria - see design guide chapter 7 and 11
- Stopping Sight Distance is a controlling criteria - see design guide chapters 7,11 and 4
  check current AASHTO standards
- Strive to achieve minimum grades for drainage purposes - ditches and curb gutters
- Look at minimum length of vertical curve
- Consider the property impacts of grade changes
- Long straight edges and triangles are valuable for setting PI's and checking existing SSD

1) Plot existing ground profile in mx the longsection LC10
2) Use triangles or other straight edges to analyze SSD for the exist. Vertical curves
3) Plot critical elevations - buildings / drives etc…
4) "Play" with PI's (*variables to use are: length of curve, PI station, and PI elevation)*
5) Run Verat file
6) Check vertical curve data particularly SSD/HLSD
7) Check impacts to: buildings / ROW / entrances / wetlands / cost /earthwork
8) Revise PI's and curve lengths in the Verat file to achieve a vertical alignment that satisfies the required design criteria.
9) Revise and Run verat file until the alignment meets the required standards and constraints.
10) Cut and plot preliminary cross sections to verify the profile will work.

> Creating preliminary design strings before cutting the sections may help in checking the impacts - also creating a file that only cuts sections at critical points such as drives saves some effort as well.

For overlay and reclaim type areas a spline grade can be created using vcusp or by amending the m string to have a certain depth over the existing ground profile (L string). This can be interspersed if necessary with the verat profile within the same input file.

Create Design Strings

- Travel lanes *(based on typical section widths)*
  Superelevation design - see chapt. 5 (*superelevation rate is a controlling criteria*)
- Design Turn lanes if needed
- Shoulders *(based on typical section widths)*
  Modify if necessary to avoid exceeding the maximum rollover rate of 8%.
- Design Islands if needed
- Create curb, guard rail, side walk and ditch strings **if** those areas are known at this time
  (See the section on template design)

Side Road Design See Highway Design Guide chapter 8 and mx design guide

- ❑ Set Horizontal Alignment
- ❑ Set Vertical Alignment (see page 8-71 in the Highway Design Guide for maximum grades approaching an intersection
- ❑ Create edge of travelway and shoulder strings
- ❑ Create Radii

- ❑ Check Radii with the design vehicles turning template(s) - Chapter 8
- ❑ Consider drainage / basin placement
- ❑ Check intersection sight distance

PRELIMINARY ALIGNMENT COMPLETE MILESTONE

Driveway/entrances design (See Highway Design Guide Chapt. 8)

- Check the applicable Access Management standards! (work with ROW and traffic team members)
- Pay particular attention to the standard details
- Do not exceed 9% grade change in 6 feet - use less than the maximum whenever possible
- Drives over 9% will be paved
- If a drive slopes down to a garage or building give it a "bump" if at all possible even if there is no curb. This will help limit water that may be channeled by snow banks in the winter from running into the entrance.
- For sharply skewed drives create an alignment and cut the long section. This will give the true grade of the existing ground to more accurately determine the correct drive slopes.
  (*Note: mx design software now allows for creating skewed cross sections)*
- On wide gravel or paved yards try to determine a consistent offset to grade to even though the drive slope may vary slightly across that width.

- In wide paved yards islands may be used to control access for safety. (See the Design Guide for maximum opening widths)

Cross Section Template Design

☛ **(Throughout the design process be thinking about drainage and drainage outlets)**

Determine Curb Areas

Used for:
- ◈ Delineating the roadway from abutting properties in urban situations
- ◈ Channels roadway water to suitable outlets - used with catch basins and or downspouts
- ◈ Prevents edge erosion in cut situations where ditches are not practical
- ◈ Sometimes used in conjunction with Guard Rail on the low side of superelevated curves - minimizes erosion
- ◈ Used to reduce slope (ROW) impacts in tight situations
- ◈ Used to create islands / control access
- ◈ Used to delineate sidewalks

Types of curb: **Bituminous type 3**

Mold 1 - barrier curb - used with sidewalks on low speed roads (*40 mph and under*) See MDOT Highway design guide chapt. 6

Mold 2 - mountable - generally used in non-sidewalk areas. For higher speed roads (*45 mph and higher*) curb should be installed so that the reveal does not exceed 6 inches on state highways and so that it does not exceed 4 inches on National Highway System roads

In general curb should be avoided if practical on high speed roads!

☛ **NOTE!**(*When mountable curb is used the clear zone offset is **not** reduced!!*)

Granite

Type 1 - barrier curb - used with sidewalks and non sidewalk areas - low speed roads only- higher traffic volumes - more durable than bituminous

Type 5 - sloped - mountable - usually used for traffic islands in higher volume urban areas

Other considerations:

- Use a 1:6 slope or flatter behind curb in fill situations to provide adequate support **or** create a 3 to 5 ft. shelf behind the curb (if there is no sidewalk) then 1:3 or flatter.
- In cut areas try to maintain a 3 to5 ft. "shelf" with a 6% slope behind the curb for snow storage

- Longer runs of curb generally will require catch basins and underdrain and possibly downspouts. Short runs of curb may not require catch basins or underdrain
- Check gutter grades to allow for proper drainage - min. gutter grade is 0.5 %
- On the high side of superelevations where there is curb it may necessary to provide a small swale ditch to intercept side slope sheet flow runoff

Determine Ditch Areas

- Allows drainage from the road way base
- Intercepts side slope drainage preventing its entrance into the roadway base
- Min. grade is 0.5 %
- Usually the depth of the ditch below subgrade should be at least 12 inches
- Sometimes when berm ditches or other shallow ditches are required underdrain may be needed as well
- Plan for erosion control
- Create ditch strings in mx
- Consider using rounded ditches in lawn areas

Guard Rail

Existing Guard Rail

- ✓ Refer to latest Guardrail Policy applicable to the type of road for upgrade discussion
- ✓ Check length of need - See Design Guide chapter 10
- ✓ Check condition - Can it be reset? / Does it need to be modified?
- ✓ Do the terminal ends need to be upgraded?
- ✓ Can the slopes be flattened and the Guard Rail eliminated?
  - ▪Consider Safety
  - ▪Consider ROW impacts
  - ▪Consider wetland impacts
  - ▪Max. fill height allowed without guard rail

See Design Guide Table 6-1 for discussion of fill slopes and fill height

New Guard Rail

- → Remember guardrail is a last resort - consider ways to eliminate need for it.
- → Determine point of hazard
- → Determine length of need (distance beyond point of hazard).
- → Use sound engineering judgment before making final recommendation.

➥ Refer to Design Guide Chapter 10 for discussion of:

- Point of hazard (obstacles within clear zone, steep slopes, embankment height etc.)
- Length of need (different methods required for different situations)
- Acceptable offset and other location issues
- Bridge approach rails
- Median guardrail

Guardrail End Treatments

- NCHRP 350 end treatments to be used on NHS and non-NHS

- Refer to latest Guardrail Policy for accepted NCHRP 350 systems and other changes.

- Refer to Design Guide Chapter 10 for a discussion of alternate end treatment types that may be used.

Create Slope Lines (Cuts / Fills) *see applicable standards in design guide(s) - see chapter on cross section elements*

Consider drainage - Don't trap water / Outlets

Some typical slopes used are: 1:4 (1 vert. /4 hor.) recoverable in- slope
1:3 (1 vert. /3 hor.) non- recoverable in- slope
1:2 (1 vert. /2 hor.) guard rail slopes and ditch backslopes and in some other cut situations such as behind sidewalks or in conjunction with a berm behind curb

Other Design components

- Sidewalks
- Retaining Walls- If necessary to match slopes see geotechnical team member for advice and design
- Clear zone issues
- Tree removal - consider possible replacement (check with landscaping unit)
- Truck Lanes
- By-pass lanes
- Exclusive turn lanes
- Island Design
- Signal requirements / Cross walk locations – Check with Traffic team member
- Landscaping elements such as shrubs and trees
    - Check with landscaping unit
    - Consider project budget
    - Ensure proposed landscaping does not obstruct sight distance

READY FOR FINAL DESIGN MILESTONE

Drainage Design (Design Guide chapter 12)

Drainage Design Sequence

Check with maintenance division for pipe performance history or othe drainage problems.

I. Locate
- Catch Basins
- Outlets
- Stub Inlets
- Drainage runs

II. Request Drainage Study *(Provide contour roll plots / cross sections / Catch Basin and Pipe locations)*

III. Identify potential utility conflicts and get additional information - try to resolve

IV. Number Catch Basins *(Optional - some in construction like it)*

V. Determine Flowlines (*work back from outlet elevations*)

VI. Determine Flows for pipes using drainage procedures in chapt. 12 Design guide (*work from high elevations towards lower elevations*)

VII. Determine pipe sizes using drainage procedures in chapt. 12 Design guide

VIII. Check gutter spread if deemed necessary

IX. Request test pits if necessary in order to resolve conflicts.

X. Determine the correct BMP standards to be used for erosion and stabilization - See MDOT Best Management Practices Manual and environmental team member

Drainage change checklist

___ Drawing details on cross sections

___ Drawing details on plan sheets

___ Construction note sheet

___ Construction notes on cross sections

___ Estimate comps
- Drainage items
- Structural Excavation
- Gravel Estimate
- Earthwork Summary

___ Estimate Form
___ Estimator
___ Quantity Sheet

BASIC HIGHWAY DESIGN CHECKLIST

Revised December 2004

___ Drainage Sheet

Geometrics-Curb Layout - required for granite curb

Erosion Control - See BMP manual

Final Project checklist - See Highway Design Guide Chapter 1

Preliminary Field Inspection

- ⇨ How does project ride?
- ⇨ Look at pavement condition - what kind of deterioration if any
  - Areas of rutting
  - Areas of cracking - what type and how bad
- ⇨ Existing shoulder condition
- ⇨ Check for obvious horizontal and vertical alignment problems
- ⇨ Check side road alignments where they connect to the main road
- ⇨ Check intersection sight distance
- ⇨ Look for obvious drainage problems
- ⇨ Note wetland areas
- ⇨ Check condition of existing drainage structures and verify size noted on plans (culverts / catch basins / box culverts) *Replace? Extend? Eliminate? Change location?* CB's *Rebuild/Alter/Adjust/Replace?*
- ⇨ Culvert outlet ditches
- ⇨ What condition is the curb in?
- ⇨ Are pedestrian ramps needed?
- ⇨ Note areas of erosion relating to the roadway
- ⇨ Is ditching needed?
- ⇨ Note condition of existing ditches
- ⇨ Are there buildings close to the road?
- ⇨ Are islands needed? Consider Access Management standards
- ⇨ Note unusually steep drives
- ⇨ Is tree trimming needed
- ⇨ Roadside safety
  - ❖ Are there hazards (DFO's) within the clear zone area? - trees / large rocks /ledge / poles etc…
  - ❖ Are there dangerous embankments or structures requiring new guard rail?
  - ❖ Existing Guard Rail

Field Inspection Supplies

Safety vest
Half size / full size plans
Marking pens
Camera / film
Folding rule
Measuring tape
Scale
Hard Hat - *if in construction site*
Steel Toes - *if in construction site*

- ❖ Invite project Team
- ❖ Maintenance representative
- ❖ Town representative (Optional)

- Check point of need - See Design Guide chapter 10
- Check condition - Can it be reset? / Does it need to be modified? / replaced?
- Do the terminal ends need to be upgraded?
- Can the slopes be flattened and the Guard Rail eliminated?
  - Consider ROW impacts
  - Consider wetland impacts
  - Max. fill height allowed without guard rail

- Check for additional survey needs

Final Field Inspection

____ Check plans with field conditions
____ See how slopes match - what impacts - drainage problems
____ Check entrances
____ Verify island locations
____ Check wheel chair ramp locations
____ Look for possible water problems
____ Check proposed drainage outlets and locations of all drainage structures
____ Check DFO's within slope lines
____ Verify proposed Guardrail locations
____ Check slope grading around buildings and other sensitive areas
____ Note areas for the different types of seeding
____ Note special erosion control needs
____ Check for utility problems - with utility team member
____ Verify project limits
____ Verify curb locations
____ Check clearing locations
____ Note locations of cellar drains

BASIC HIGHWAY DESIGN CHECKLIST

Revised December 2004

Construction Notes

Work items that are typically covered by construction notes.

- ___ Tree removal
- ___ Stump removal
- ___ Clearing areas
- ___ Remove and Reset fence
- ___ New fence items
- ___ Remove and Reset Stone Wall
- ___ Drainage Items
  - ___ Remove existing Catch Basins
  - ___ Manholes & Catch Basins
  - ___ Altering Manholes or Catch Basins
  - ___ Adjusting Manholes or Catch Basins to grade
  - ___ Culverts
  - ___ Extending culverts
  - ___ Underdrain
  - ___ Underdrain Outlets
- ___ Entrances
  - ___ Paved entrances
  - ___ Gravel entrances
  - ___ Field / woods entrances
  - ___ Crushed Stone Entrances
- ___ Conrete walks
- ___ Paved walks
- ___ Concrete Steps
- ___ Pedestrian ramps
- ___ Curb items
- ___ Reset Curb
- ___ Ditching
- ___ Landscaping Items
- ___ Retaining walls
- ___ Guard Rail Items
- ___ Table of Superelevation
- ___ Permanent Erosion Control Items
  - ___ Riprap Downspouts
  - ___ Culvert End Protection (riprap)
  - ___ Riprap Aprons
  - ___ Erosion Control blanket
  - ___ Stone Ditch Protection
- ___ Numerous oddball notes covering unique or unusual situations

General Notes

A list of standard general notes can be found in the Highway design guide chapter 2 as well as on the W drive under MDOT microstation utilities / Spreadsheets and notes.

These notes may need to be modified for a special situation on a given project.

In addition to existing notes, new general notes may need to be written to cover unique conditions on a specific project.

Typical Plan Package Components

- ___ Title Sheet
- ___ Typical Section Sheet

Review required specifications and special provisions

Assemble PS&E

___ Quantity Sheet / Earth Summary
___ General Notes
___ Special Details (If any)
___ Construction Notes
___ Geometric sheets (used for granite curb layout and geometrically complex jobs)
___ Profile Sheets
___ Plan Sheets
___ Cross Section Sheets
___ ROW maps

PLAN IMPACTS COMPLETE MILESTONE

Urban and Arterial Highway Program

Jerome Casey, Program Manager
624-3344

Memorandum

To: Urban & Arterial Highway Program Designers
cc:
From: George Macdougall, Design Support Engineer
Date: July 15, 2002
Subject: Special Provisions and Supplemental Specifications - Process and Guidelines

Attached are processes for both Special Provisions and Supplemental Specifications. Also included are guidelines for writing and formatting specifications with example specifications attached.

Some confusion exists as to the definitions of Special Provisions and Supplemental Specifications. Compounding the confusion is the existence of two types of Special Provisions, commonly used and project specific.

There are references to the following people in these processes:
Contract Coordinator - This is Steve Levesque for U&AHP.
Specifications Engineer - This is Scott Bickford for the Department and is part of the Contracts Section.
Design Support Engineer - This is George Macdougall for U&AHP.

The Standard Specifications define the following terms;

PLANS;

The approved plans, profile, typical cross sections, working drawings, and supplemental drawings or exact reproductions thereof, which show the location, character, dimensions, and details of the work to be done.

STANDARD SPECIFICATIONS:

A Specification that has been adopted by the department as a standard to do work by and appears in the printed book of Standard Specifications

SUPPLEMENTAL SPECIFICATIONS;

Additions and revisions to the Standard Specifications that are adopted subsequent to issuance of the printed book of Standard Specifications

SPECIAL PROVISIONS;

Additions and revisions to the Standard Specifications and Supplemental Specifications covering specific conditions on an individual project.

A commonly used Special Provision is a specification that will always be used such as SECTION 107, RELATIONS WITH AND RESPONSIBILITY TO PUBLIC (Soil Erosion and Water Pollution Control) or a specification used whenever a particular item is called for such as SECTION 606, GUARDRAIL (Bridge Transition). Special Provisions like these are very close to Supplemental Specifications. A few reasons why they are not Supplemental Specifications is that some or all of the Special Provision is prone to changes or the possibility exists that it may be discontinued in the future.

A project specific Special Provision is used given a certain requirement or condition on a particular project warrants such individual specifications. A typical example is a utility Special Provisions.

The importance of good specifications cannot be overstated. For example, Special Provisions govern over the Plans which govern over Supplemental Specifications, which govern over Standard Specifications.

Attachments

MAINE DEPARTMENT OF TRANSPORTATION

BUREAU OF PROJECT DEVELOPMENT

URBAN AND ARTERIAL HIGHWAY PROGRAM

GUIDE FOR PREPARING

SUPPLEMENTAL SPECIFICATIONS

&

SPECIAL PROVISIONS

FOR

CONSTRUCTION CONTRACTS

FOR USE WITH THE STANDARD SPECIFICATIONS

SUPPLEMENTAL SPECIFICATIONS PROCESS

1. Determine need for Supplemental Specifications.

2. Engage team members, designers and other resources as necessary.

3. Review existing Supplemental and Special Provisions. A workable specification may have been previously developed or one may be available that would serve as a good “go by”. The Specification Engineer maintains a database for commonly used Special Provisions and Supplemental Specifications.

4. Develop draft copy of Supplemental in its proper format and attach a <u>brief</u> synopsis.

5. Distribute for review and comment to appropriate resources and Design Support Engineer.

6. Adjust Supplemental if necessary.

7. Distribute Supplemental to the Contracts Coordinator. He will make the proper distribution for review and comment.

8. The Supplemental Specification will be adjusted by the Contracts Section, Specification Engineer and the author(s).

9. Distribute to appropriate personnel.

10. The Specification Engineer will distribute to FHWA to seek concurrence, after which the Supplemental will be input into the database.

SPECIAL PROVISIONS PROCESS

Determine need for Special Provision.

1. Determine need for Special Provision.

2. Determine if Special Provision is project specific or will be commonly used.

3. Engage appropriate team members, designers and other resources as necessary.

4. Review existing Special Provisions. A workable Special Provision may have been previously developed or one may be available that would serve as a good "go by". The Specification Engineer maintains a library of project specific Special Provisions and a computer database for commonly used Special Provisions and Supplemental Specifications.

5. Develop draft copy of the Special Provision in its proper format and attach a brief synopsis.

6. Distribute for review and comment to appropriate resources and the Design Support Engineer.

7. Adjust Special Provision if necessary.

8. Distribute Special Provisions for review and comment to Contract Coordinator, appropriate Bureaus, Programs and/or Sections.

9. Adjust Special Provision if necessary.

10. Distribute to resources so they will have a copy for future reference.

11. Distribute to Contracts Section. If the Special Provision is project specific it should be submitted with the PS&E package. If it is a new or revised commonly used Special Provision it may be included in the PS&E package, if it is to be used on a project at that time, or it may be submitted independently if it is to be used on future projects. In either case, commonly used Special Provisions should be flagged so that the Specification Engineer can include them in the computer database and make distributions for their future use.

PROCEDURE FOR PREPARING
SUPPLEMENTAL SPECIFICATIONS AND SPECIAL PROVISIONS

Since many individuals are contributing to the Specifications, the following will help obtain uniformity.

1. When typing the final copy, use the same arrangement and form as that of the Standard Specification; i.e. Description, Materials and Construction Requirements.

2. Use the correct designation, i.e., "Supplemental Specification" or "Special Provision". The order of precedence is important and is clearly defined in the Standard Specifications.

3. Leave at least 1-inch margin on each side of the page. This is important since the pages are bound and must be able to be read easily.

4. The heading at the top of the page of Supplemental Specifications should be arranged as follows:

October 1, 1981

SUPPLEMENTAL SPECIFICATION
<u>SECTION 304</u>
AGGREGATE BASE AND SUBBASE COURSE

5. The heading at the top of the page of Special Provisions should identify the project and should be arranged as follows:

Town
Project
October 1, 1981

`

SPECIAL PROVISION
<u>SECTION 603</u>
PIPE CULVERTS AND STORM DRAINS
(Bedding)

6. If the Supplemental Specification or Special Provision supersedes one previously written, the following information should be included in the upper right hand corner directly under the current date.

7. If diagrams and charts are used, they should be identified in the same manner as a written Supplemental Specification or Special Provision.

8. The initial of the author should be shown in the lower left hand corner of the last page.

9. Multiple page Specifications or Special Provisions should be numbered at the bottom center of each page. Such as “1 of 3”.

10. A copy of all Supplemental Specifications and Special Provisions should be sent to the Specification Engineer.

IMPORTANT QUALITIES TO CONSIDER WHEN WRITING SPECIFICATIONS

Important qualities in a specification are:

1. Fairness
2. Clearness
3. Completeness
4. Correctness
5. Economy

1. Fairness: A specification should not be designed to "get something for nothing" by concealing its content. It is not fair to attempt to put all risks on the Contractor. Requirements must be realistic and represent what is practical to obtain for adequate quality.

   Unfairness can also arise from the use of indefinite phrases, such as, "as the Engineer may direct", "acceptable" and "as required". Such language places the Contractor at the mercy of the Engineer. There may be occasions when they may be used, but this should be restricted to situations such as color or location determinations or other factors not involving costs to the Contractor.

2. Clearness: It is important that specifications be expressed in clear language. The language should be brief and to the point.

   (a) Use simple words and terms of a single meaning.

   (b) Use technical words in their exact meaning.

   (c) Use terms in their common or local meaning.

   (d) Use nouns; not pronouns. Repeat the word at the sacrifice of elegance.

   (e) Use the same word throughout; never synonyms. Do not say "building" in one place and "house" in another when you refer to the same thing. Also do not use the same word with different meanings.

   (f) Use short sentences. The language must be clear and unmistakable.

   (g) Give directions, not suggestions. Do not say more than is necessary. Say exactly what you mean and only what you mean.

   (h) Use commas sparingly. If changing the location of a comma changes the meaning, rewrite the sentence.

   (i) Dimensions and sizes should not be included in the Specification if they can be shown on the plans. Do not repeat information which is given on the plans.

3. Completeness: Except for information set forth on the plans or standard drawings, the specifications must be complete and should describe its subject matter thoroughly. If the specification is silent as to a requirement, the Contractor cannot be expected to meet that requirement without additional payment. However, it must be also realized that it is not practical to cover all unimportant details or to provide for every possible contingency.

   Completeness need not be carried to the point of exhaustiveness since a specification is not meant to be a complete treatise on the subject and is not the proper place for the writer to disclose all he knows about the subject.

   Avoid whims and personal requirements. The reason for a requirement need not be included in specifications. This leads to disputes between the Engineer and the Contractor.

4. Correctness: It is the specification writer's responsibility to include the really essential characteristics of the subject matter along with realistic numerical limits, if such limits are required. The fact that a specification has been in force for a number of years does not necessarily assure technical adequacy.

   All references and cross references should be checked for correctness, conflicts and omissions. Check AASHTO and ASTM Specification references for the correct numbers.

5. Economy: A practical specification is one that assures the highest dollar value of the resulting construction. Every requirement has some direct or indirect cost associated with it. Whenever specifications are written or revised, each requirement should be scrutinized with respect to its effect on cost.

   Every specification item should be studied with a review to eliminating non-essential requirements and permitting the use of new materials, methods and equipment.

LIST OF PREFERRED USAGE

The following is a list of preferred word usage.

1. “Linear” not “lineal”.

2. “Amount” refers to money, “quantity” refers to material.

3. “Said” - do not use as an adjective such as “said aggregate”, instead, use “this” or “these aggregates”.

4. “Same” - do not use as a pronoun such as “connected to same”, instead, if necessary, use “it”, “them”, or a similar pronoun.

5. “And/or” - do not use this term, instead, say “…. or …. Or both” or some other phrase.

6. “Etc.” - do not use in the specification.

7. “Must” and “shall” - do not use interchangeably. Generally, “shall” is used in the Maine specification.

8. “Shall” and “will” - “shall refers to what the Contractor is required to do. “Will” refers to what the “State” will do.

9. Do not omit articles. Do not say “Contractor shall scarify sub-grade”; say “The Contractor shall scarify the sub-grade”.

10. “Any”, “all” - do not say, “The Contractor shall correct any defects”; instead, say “The Contract” shall correct “all defects”.

11. “Either”, “both” - “either” implies a choice; “both” means one and the other.

12. Use the word “amended” when making an addition. Example: “This subsection is amended by the addition of the following:”.

13. Use the word “revised” when changing existing procedures or requirements. Example: “This subsection is revised to read as follows”:

14. Do not use such words as, “properly” or “adequate”. These words are too indefinite.

15. “Insure”, “ensure” and “assure” all mean “to make certain”; for uniformity, use “assure” in the Maine specification.

16. Do not use foreign words or phrases, such as “in lieu of”.

17. Do not use parentheses or underline phrases in the text. No requirement should be considered more important than others.

18. Numbers should be written numerically, except at the beginning of a sentence

19. Don’t use trite phrases such as: “it shall be incumbent upon”, use “shall”, “by means of”, use “by”.

20. Cross references to Sections should include both the Section number and the Title. Refer to Subsections by number only. Such as “Section 310 Bituminous Stabilized Base” or “Subsection 310.04”.

21. Symbols: In general do not use symbols except in tables - instead write out the whole word.

#	number
%	percent
“	inch
‘	foot
°	degree when referring to angle
°	use °C, when referring to degrees temperature
+	plus
-	minus
“	minute
‘	second
2 x 4”	2 by 4 inches

March 1, 1993

SPECIFICATION STANDARDS

1. A header will be used on all pages to assist with identification during handling and filing.

- The header on page 1 will remain the same.

Supplemental & Common Special Provisions:	Project Specific:
January 28, 1992 Supersedes December 10, 1991	Sandy Bay 033-2(1) February 22, 1993

- A header will be used on additional pages using the following format and is to be located in the upper right corner of the page.

Supplemental & Common Special Provisions:	Project Specific:
Section 503 January 28, 1992	Sandy Bay Section 652 February 22, 1993

2. If the specification is greater than one page, pages will be numbered “1 of 3”, “2 of 3”, “3 of 3”, for example.

3. When changes are made to supplemental and common special provisions, the changes are to be made in bold type and vertical lines are to be drawn in both the left and right margins. This will help to quickly identify changes to designers, residents and contractors. Both margins should contain the vertical lines as most specifications are printed back to back which alternately binds each margin.

4. The authors and typists initials are to be placed at the end of the specification.

5. The document’s computer name is to be placed under the initials to assist with locating the document in the future.

November 1, 1995

COMMONLY USED

SPECIAL PROVISION
SECTION 606
GUARDRAIL
(Bridge Transition)

Description. This work shall consist of furnishing and installing guardrail components and their attachment to a concrete or steel bridge rail system.

Material. All materials shall conform to the requirements of the Standard Specifications and shall be of the same type as the remainder of the guardrail system.

Construction Requirements. All components shall be installed in accordance with the Standard Specifications and Standard Details at locations shown on the plans or as directed. Additional bolt holes required in the guardrail beams shall be formed by a method approved by the Engineer. Holes shall not be burned.

Method of Measurement. Each installation will be measured for payment as one unit, complete in place and accepted.

Basis of Payment. Bridge Transitions will be paid for at the contract unit price for each installation. Such payment will include furnishing and installing the thrie beam or W-beam terminal connector, doubled beam section and transition section where called for, posts hardware and any other necessary materials and labor, including the attachment to the bridge rail system required to satisfactorily complete the work.

Payment will be made under:

Pay Item		Pay Unit
606.1721	Bridge Transition - Type “1”	Each
606.1722	Bridge Transition - Type “2”	Each

DMDbrdes
bcku- spec dist #2

All Contracts

COMMONLY USED

January 21, 1993
Supersedes
August 5, 1991

SPECIAL PROVISION
SECTION 107
RELATIONS WITH AND RESPONSIBILITY TO PUBLIC
(Soil Erosion and Water Pollution Control)

A resource or resources, which are governed by the requirements of the recently amended Maine Natural Resources Act (38 MSA 480-A et seq.) and the Federal Clean Water Act (Section 404), are affected by construction activities of this project. Additional requirements for erosion and pollution control to protect these resources are contained herein.

Within these affected areas, requirements of this Special Provision shall govern over requirements of the Standard Specifications.

In the event of conflict between this Special Provision and other erosion and pollution control laws, rules or regulations of other Federal, State and local agencies, the more restrictive laws, rules or regulations shall apply.

The entire project is governed by the requirements of this Provision except when specific resource areas are identified on the plans or elsewhere in these Special Provisions. The requirements of this Provision shall apply to only specific resource areas, when identified, and not the entire project.

ENVIRONMENTAL STANDARDS

The standards described below shall be met within the resource areas on the project.

The standards are designed to insure that the construction will not unreasonably:

a. interfere with any existing recreational or navigational uses;

b. cause erosion of the soil or siltation of the water;

c. interfere with the natural flow of water;

d. harm any wildlife or fish habitat; and

e. degrade water quality

Belgrade
F-BR-032P(27)
April 18, 1995

PROJECT SPECIFIC

SPECIAL PROVISION
SECTION 502
STRUCTURAL CONCRETE
(Existing Structure Modifications)

Description. This work shall consist of the reconstruction of the concrete and granite retaining walls of the existing dam over Great Pond Outlet.

Construction Requirements. All work shall be in conformity with applicable requirements of Section 502 of the Standard Specifications, Supplemental Specifications, and Special Provisions. New construction shall match into the existing walls as shown on the contract Plans, with existing wall removal and reconstruction kept to a minimum as directed by the Engineer. The respective concrete or granite walls shall be rebuilt in kind using existing reinforcing steel or granite blocks, as appropriate.

Method of Measurement. Existing Structure Modifications will be measured for payment by the lump sum, consisting of all work required to reconstruct the existing retaining walls.

Basis of Pavement. Existing Structure Modifications will be paid for at the contract lump sum price, which price shall be full compensation for furnishing all labor, materials, equipment, and incidentals required to complete the work. Removal of the existing concrete or granite will be paid for under Item 202.19, Removing Existing Bridge.

Pavement will be made under:

Pay Item		Pay Unit
502.36	Structural Concrete Existing Structure Modifications	Lump Sum

PLHbrdes
Harddrive

May 5, 1995

SUPPLEMENTAL SPECIFICATION
SECTION 627
PAVEMENT MARKING

Section 627 - Pavement Markings is amended as follows:

627.09 Method of Measurement. Replace the first paragraph with the following:

Longitudinal lines parallel to the centerline of the roadway will be measured by the meter (linear foot) along the centerline stationing of the roadway. Other lines will be field-measured or computed. Double-yellow centerline, broken or solid, shall be considered to be one line for measurement purposes. The measurement of broken lines will include the gaps when painted and will not include the gaps when plastic. All other pavement markings will be measured by the square meter (square foot).

627.10 Basis of Payment. Replace the final paragraph, which consists of Pay Items, with the following:

Pay Item	Metric United	Pay Unit
627-61	100 mm White Pavement Marking Line	meter
627.62	150 mm White Pavement Marking Line	meter
627.63	100 mm Yellow Pavement Marking Line	meter
627.64	150 mm Yellow Pavement Marking Line	meter
627.65	White or Yellow Pavement and Curb Marking	square meter
627.67	Removing Pavement Markings	square meter
627.68	Temporary 100 mm Painted Pavement Marking Line, White or Yellow	meter
627.681	Temporary 150 mm Painted Pavement Marking Line, Yellow or White	meter
627.69	Temporary 100 mm Plastic Pavement Marking Line, Yellow or White	meter
627-691	Temporary 150 mm Plastic Pavement Marking Line, Yellow or White	meter

Pay Item	Metric Units	Pay Unit
627-61	4-inch White Pavement Marking Line	Linear Foot
627.62	6-inch White Pavement Marking Line	Linear Foot
627.63	4-inch Yellow Pavement Marking Line	Linear Foot
627.64	6-inch Yellow Pavement Marking Line	Linear Foot
627.65	White or Yellow Pavement and Curb Marking	Square Foot
627.67	Removing Pavement Markings	Square Foot
627.68	Temporary 4 inch Painted Pavement Marking Line, White or Yellow	Linear Foot
627.681	Temporary 6 inch Painted Pavement Marking Line, Yellow or White	Linear Foot
627.69	Temporary 4 inch Plastic Pavement Marking Line, Yellow or White	Linear Foot
627-691	Temporary 6 inch Plastic Pavement Marking Line, Yellow or White	Linear Foot